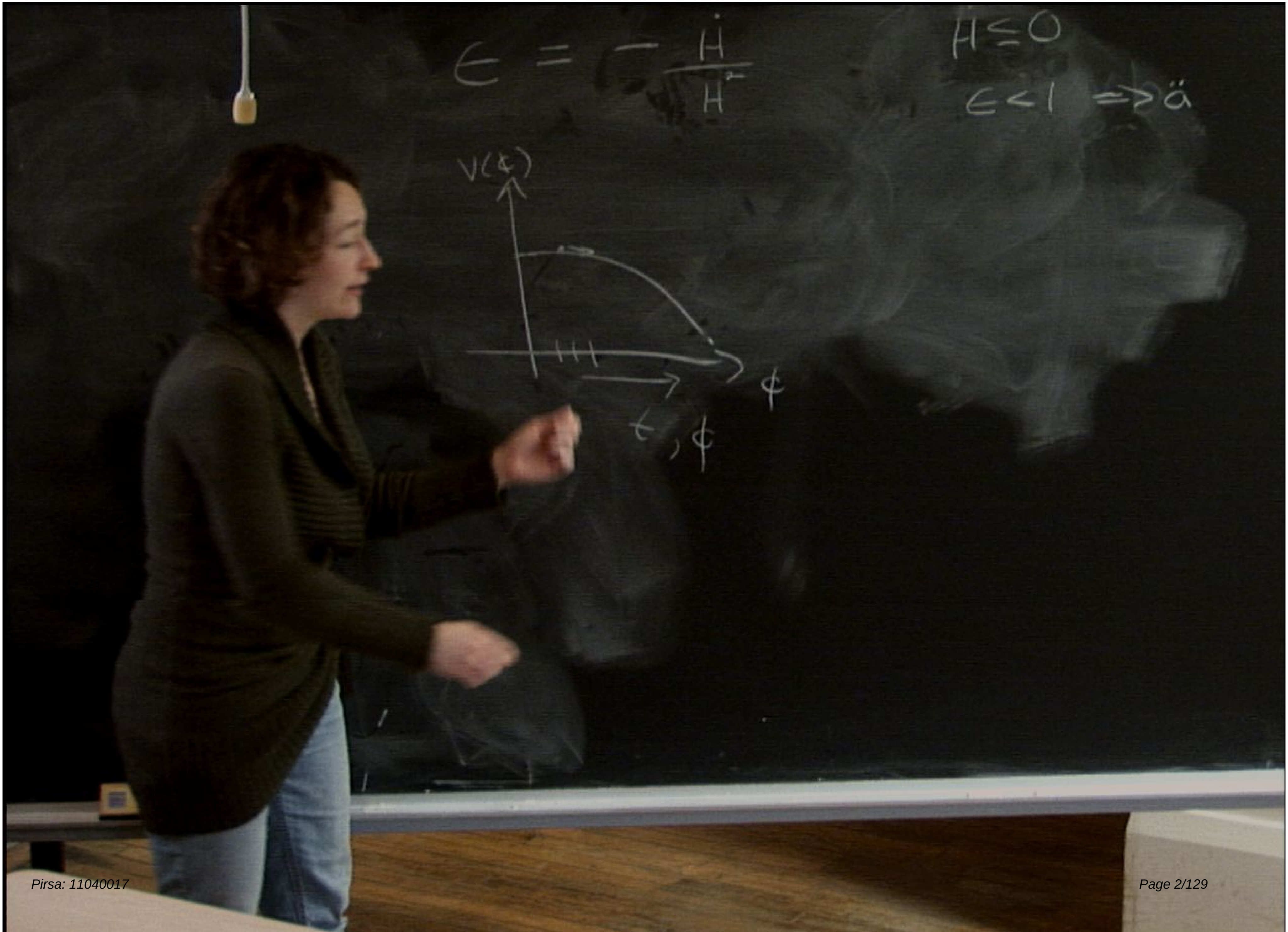
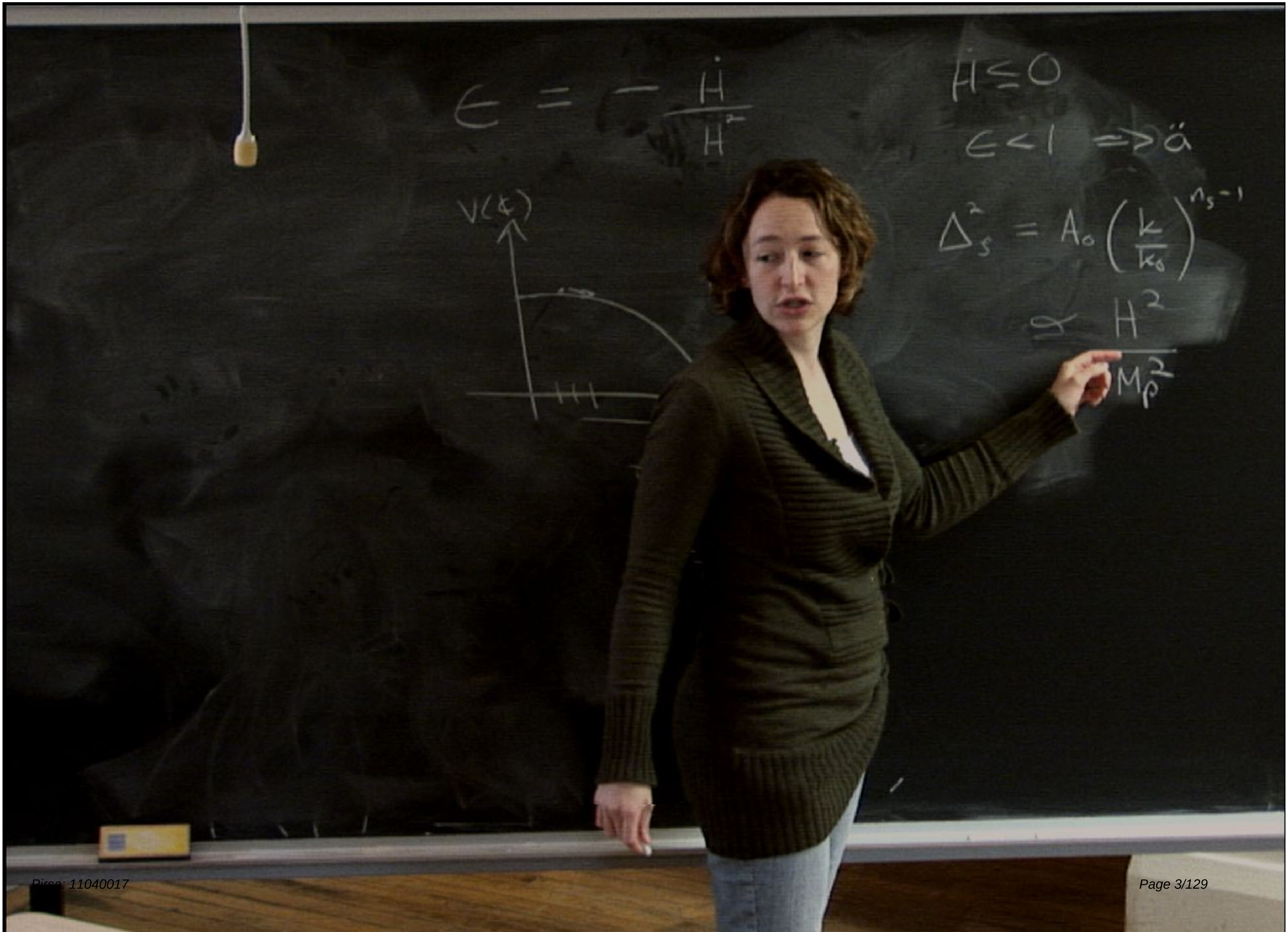
Title: Explorations in Cosmology - Lecture 11

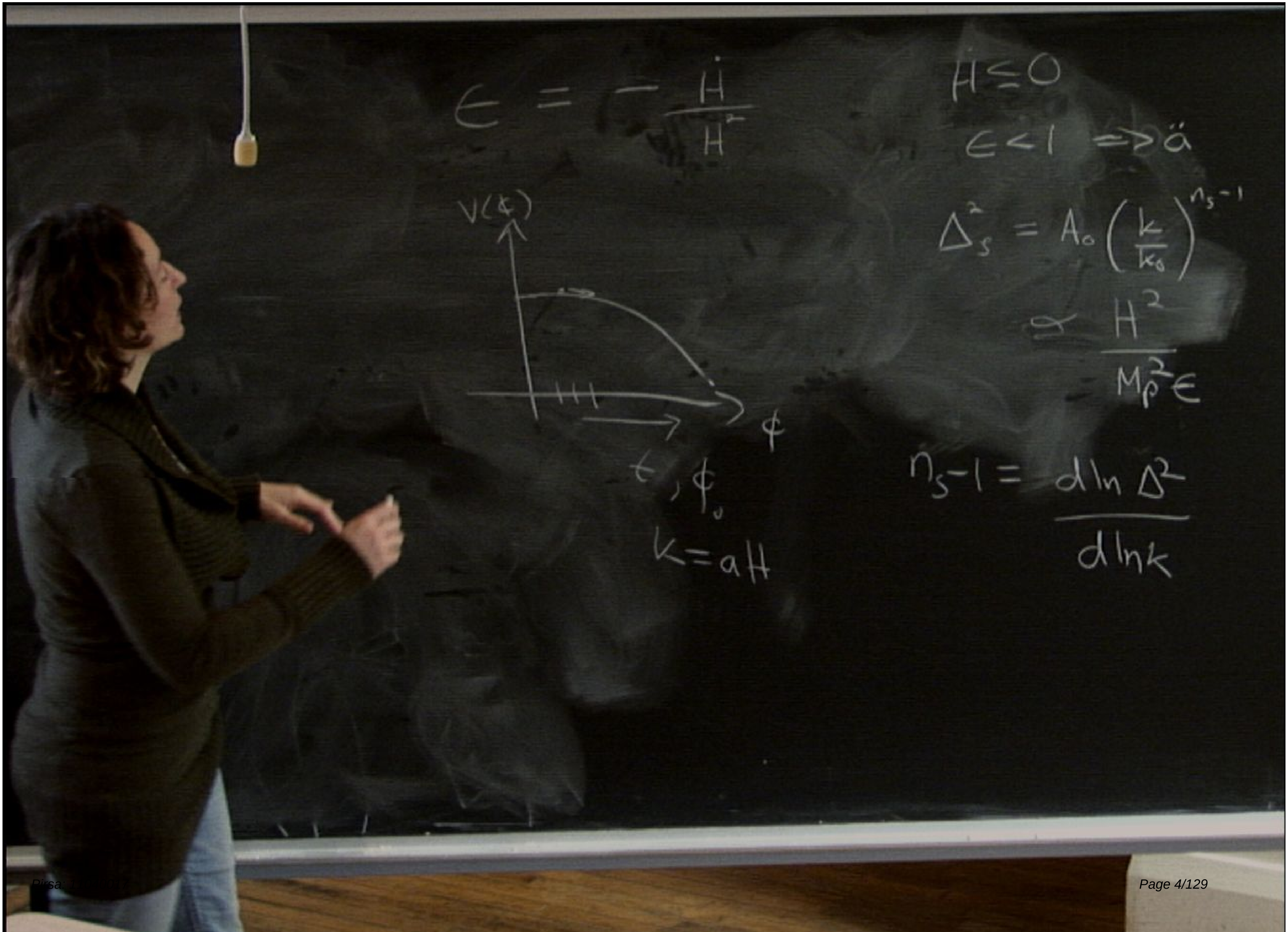
Date: Apr 18, 2011 09:00 AM

URL: http://pirsa.org/11040017

Abstract:


$\epsilon = -\frac{\dot{H}}{H^2}$
$\dot{H} \leq 0$
$\epsilon < 1 \Rightarrow \ddot{a}$
$V(\phi)$
ϕ
t, ϕ


$\epsilon = -\frac{\dot{H}}{H^2}$
$\dot{H} \leq 0$
$\epsilon < 1 \Rightarrow \ddot{a}$
$V(\phi)$
$\Delta_s^2 = A_0 \left(\frac{k}{k_0}\right)^{n_s - 1}$
$\propto \frac{H^2}{M_p^2}$



$\epsilon = -\frac{\dot{H}}{H^2}$
$\dot{H} \leq 0$
$\epsilon < 1 \Longrightarrow \ddot{a}$
$V(\phi)$
ϕ
t, ϕ_0
$k = aH$
$\Delta_s^2 = A_0 \left(\frac{k}{k_0}\right)^{n_s - 1}$
$\propto \frac{H^2}{M_p^2 \epsilon}$
$n_s - 1 = \frac{d \ln \Delta^2}{d \ln k}$

$\eta = \quad \epsilon$

$$\epsilon = -\frac{\dot{H}}{H^2}$$

$\dot{H} \leq 0$

$\epsilon < 1 \Rightarrow \ddot{a}$

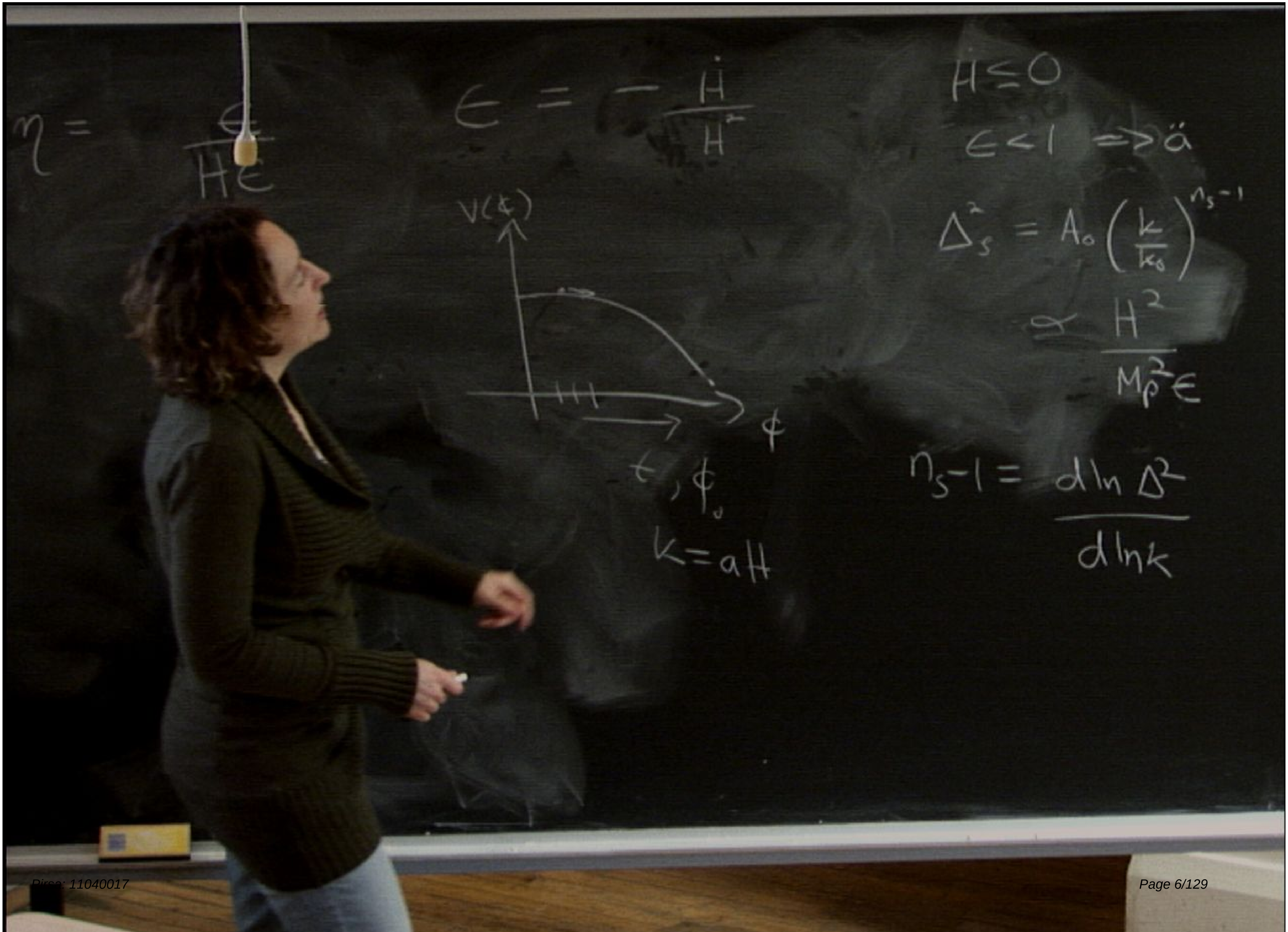
t, ϕ_0

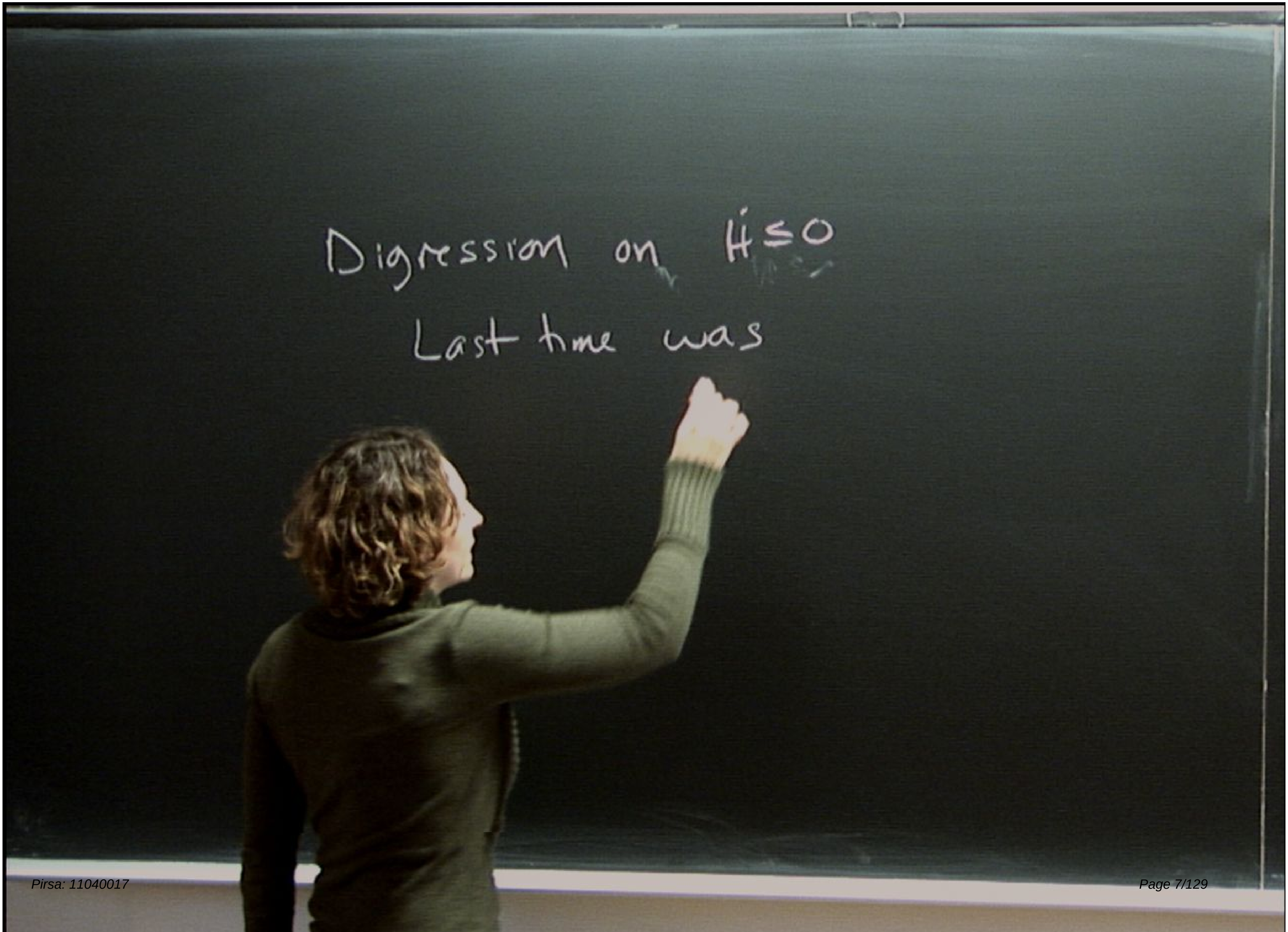
$k = aH$

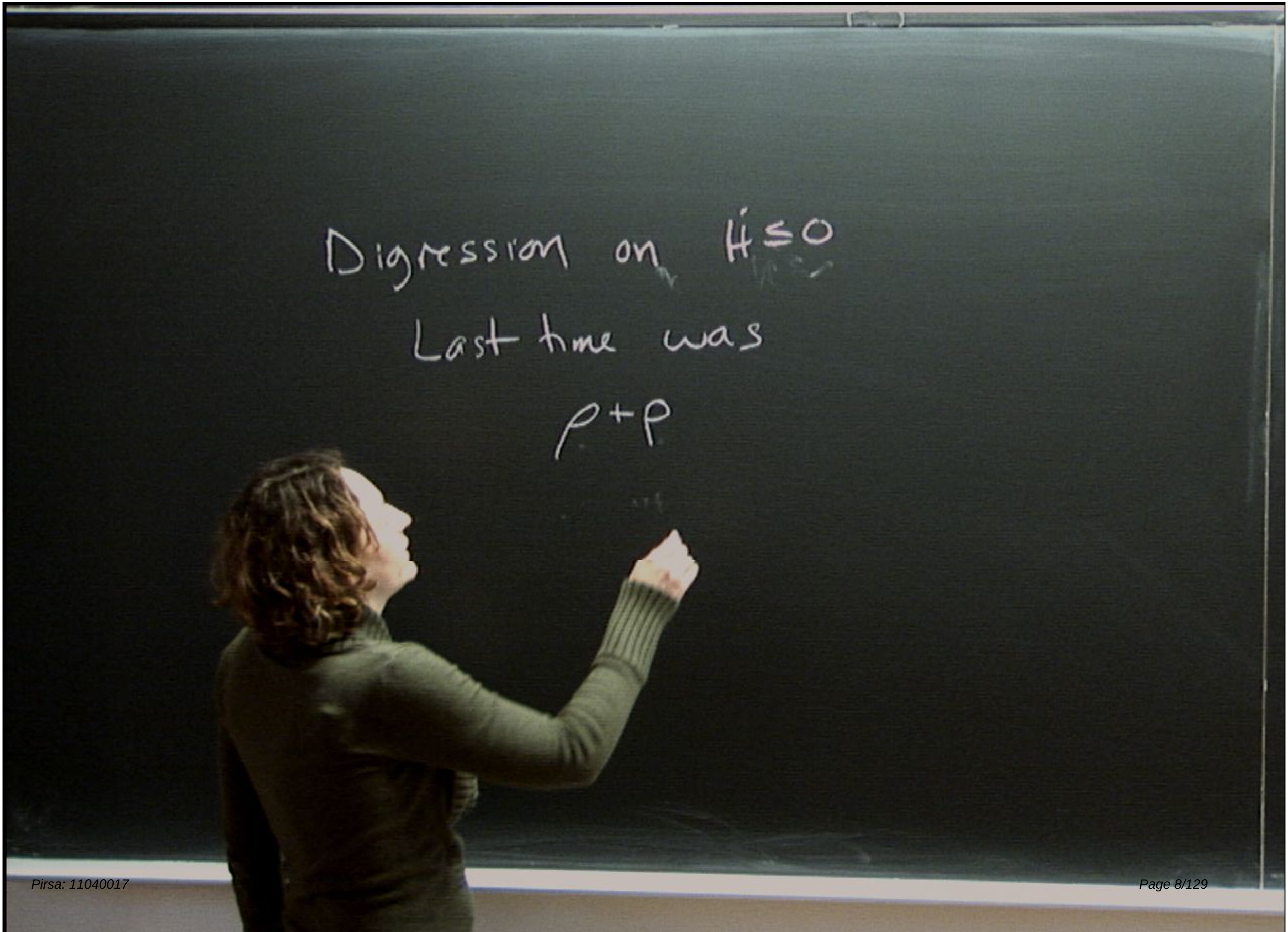
$$\Delta_s^2 = A_0 \left(\frac{k}{k_0}\right)^{n_s - 1}$$

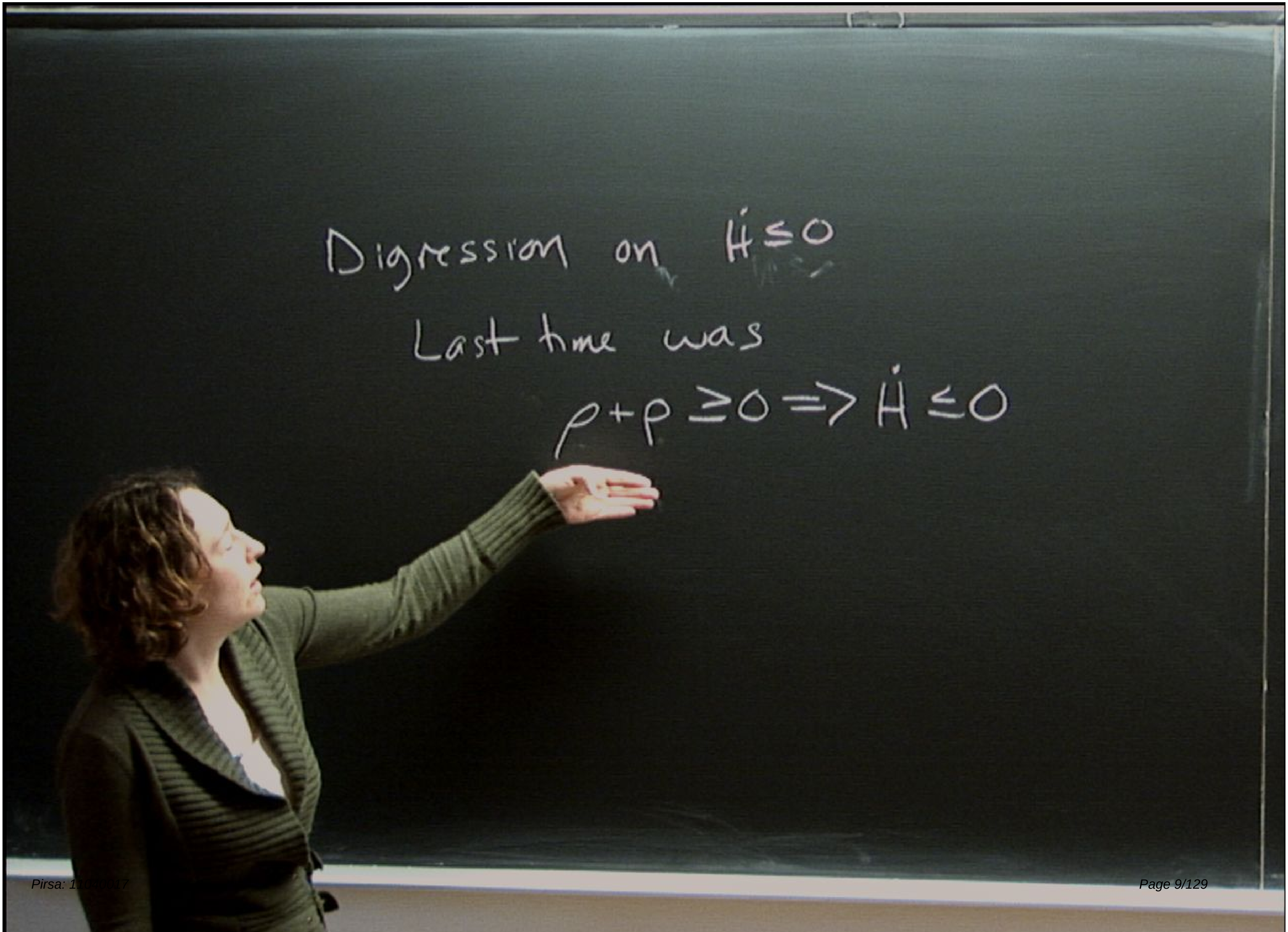
$$\propto \frac{H^2}{M_p^2 \epsilon}$$

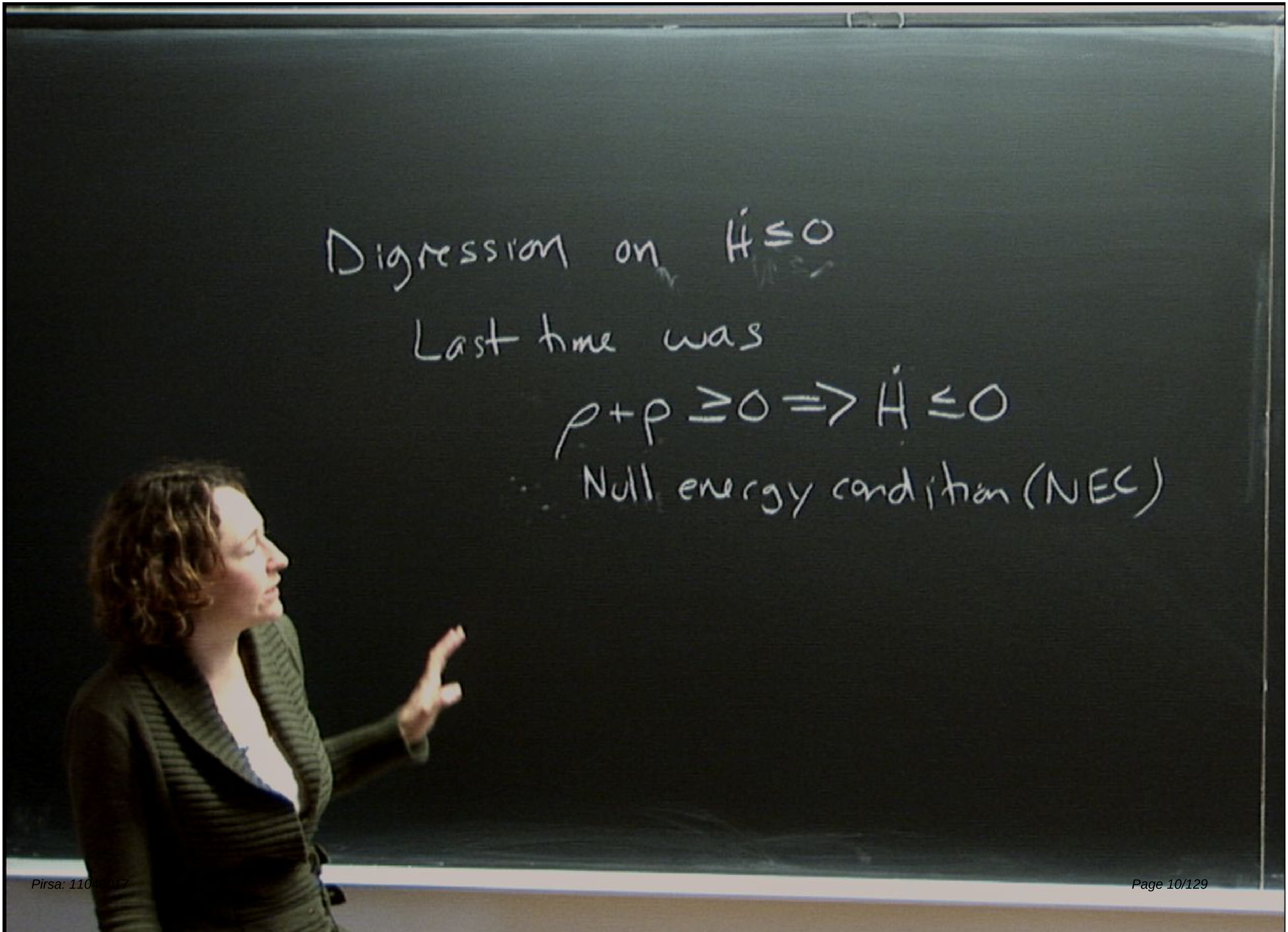
$$n_s - 1 = \frac{d \ln \Delta^2}{d \ln k}$$

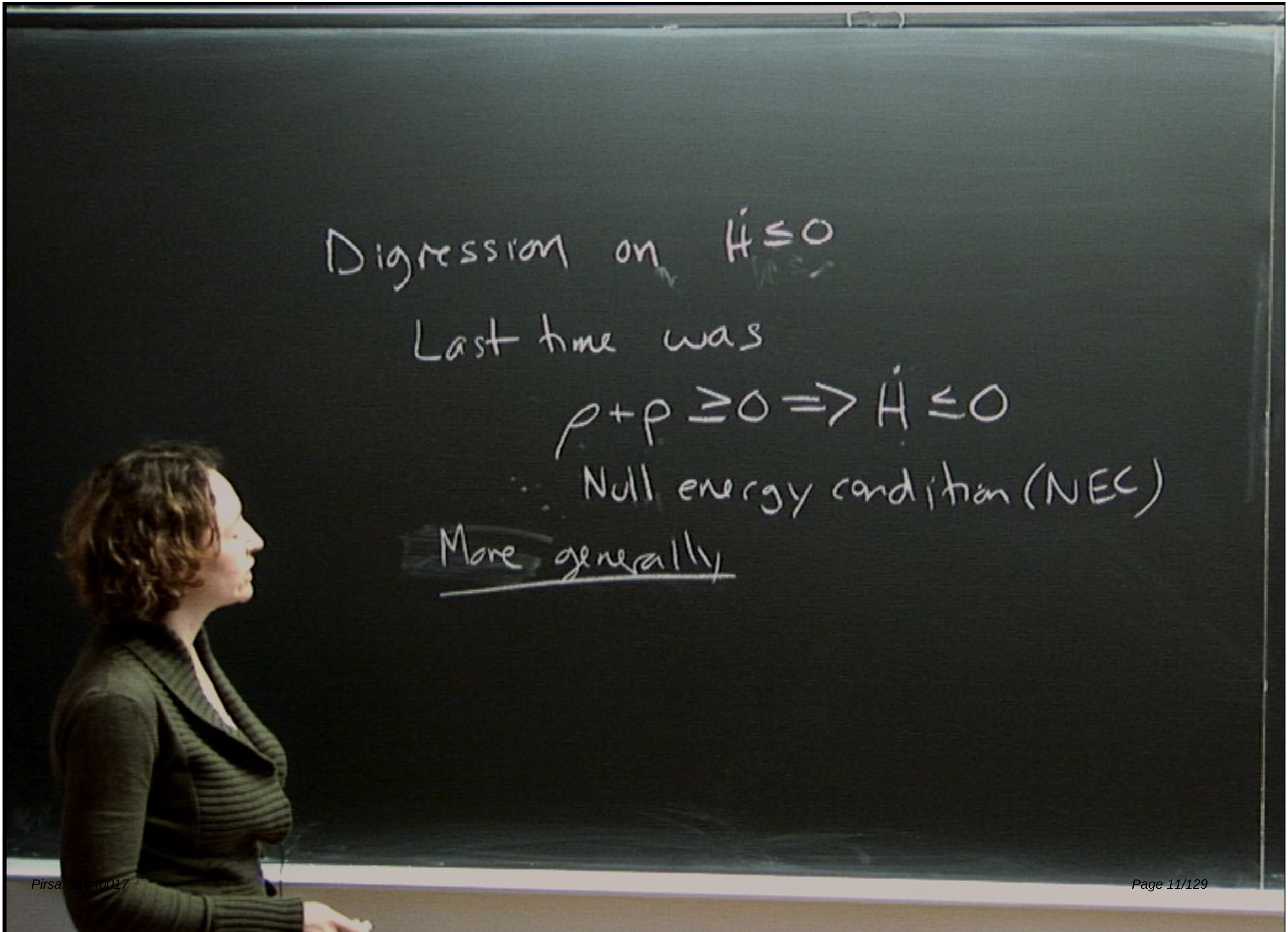

η = ε̇ / Hε
ε = − Ḣ / H²
Ḣ ≤ 0
ε < 1 ⇒ ä
V(φ)
φ
t, φ₀
k = aH
Δs² = A₀ (k / k₀)^(ns−1)
∝ H² / Mp² ε
ns − 1 = d ln Δ² / d ln k


Digression on $\dot{H} \leq 0$
Last time was


Digression on $\dot{H} \leq 0$
Last time was
$\rho + p$


Digression on $\dot{H} \le 0$
Last time was
$\rho + p \ge 0 \Rightarrow \dot{H} \le 0$


Digression on $\dot{H} \le 0$
Last time was
$\rho + p \ge 0 \Rightarrow \dot{H} \le 0$
Null energy condition (NEC)


Digression on $\dot{H} \leq 0$
Last time was
$\rho + p \geq 0 \Rightarrow \dot{H} \leq 0$
Null energy condition (NEC)
More generally

Digression on $\dot{H} \le 0$

Last time was

$$\rho + p \ge 0 \Rightarrow \dot{H} \le 0$$

$\therefore$ Null energy condition (NEC)

<u>e generally</u>

e can find geometries that are "weird" [acausal? Wormholes?]

Digression on $\dot{H} \leq 0$

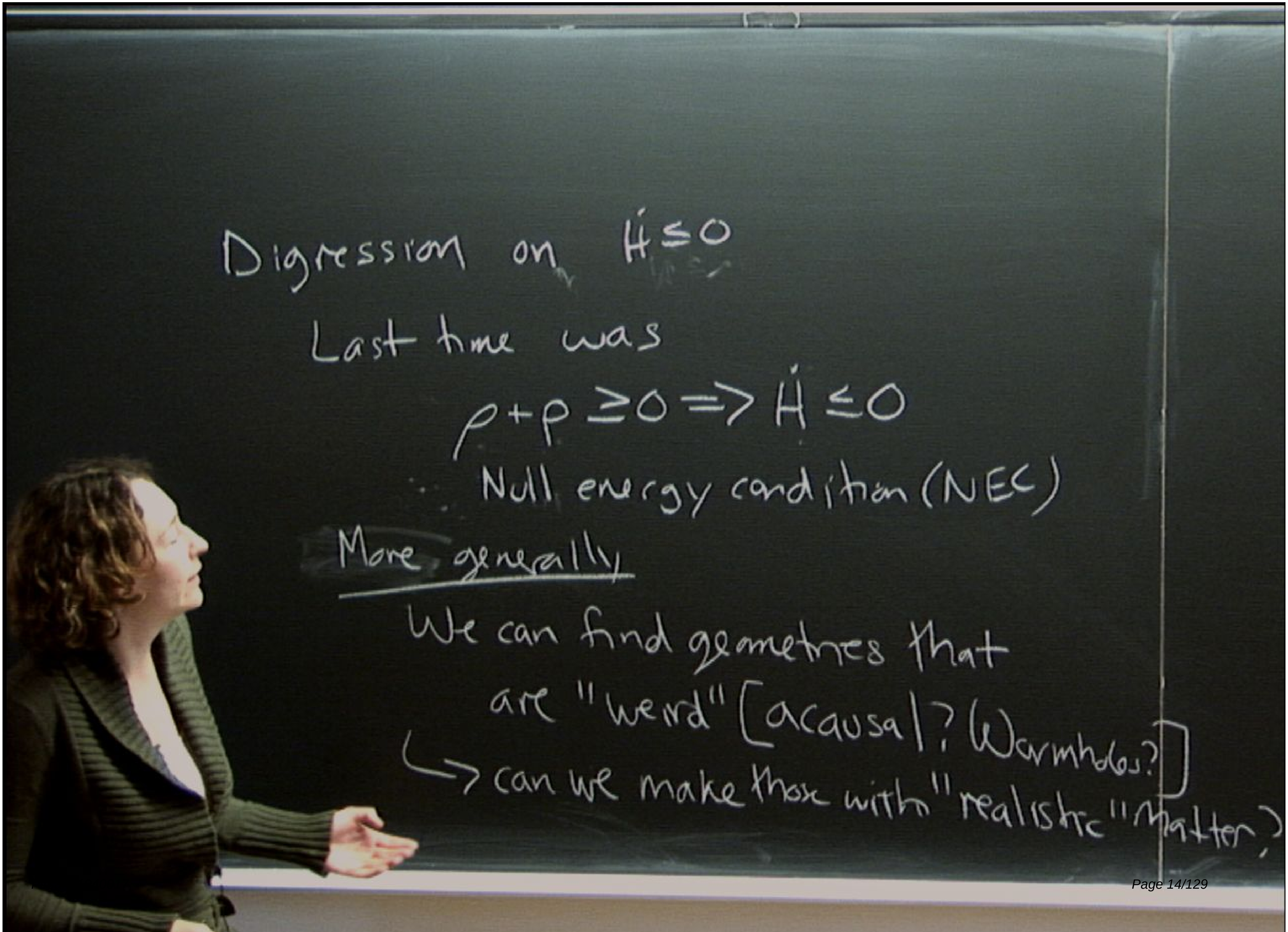
Last time was

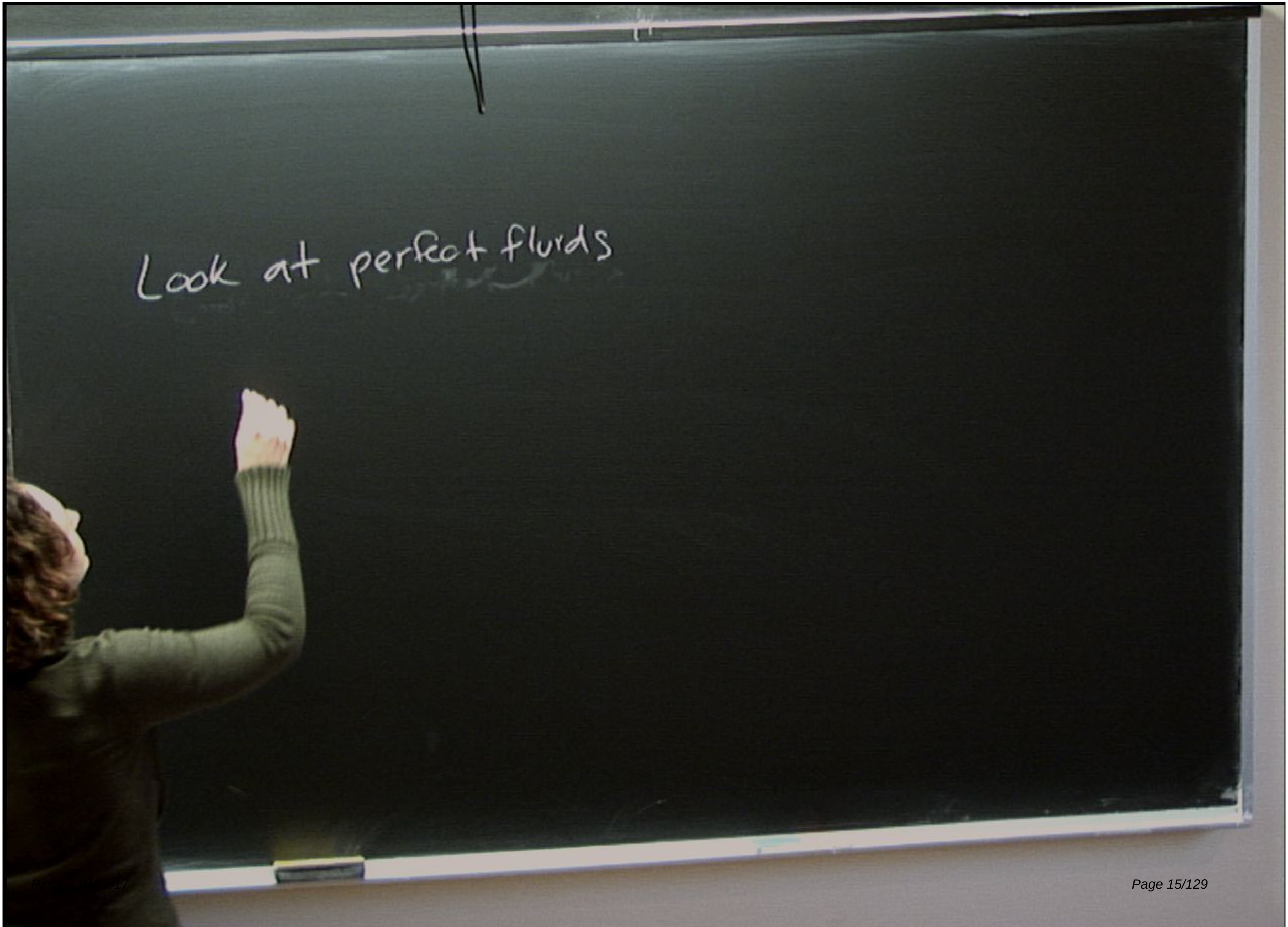
$$\rho + p \geq 0 \Rightarrow \dot{H} \leq 0$$

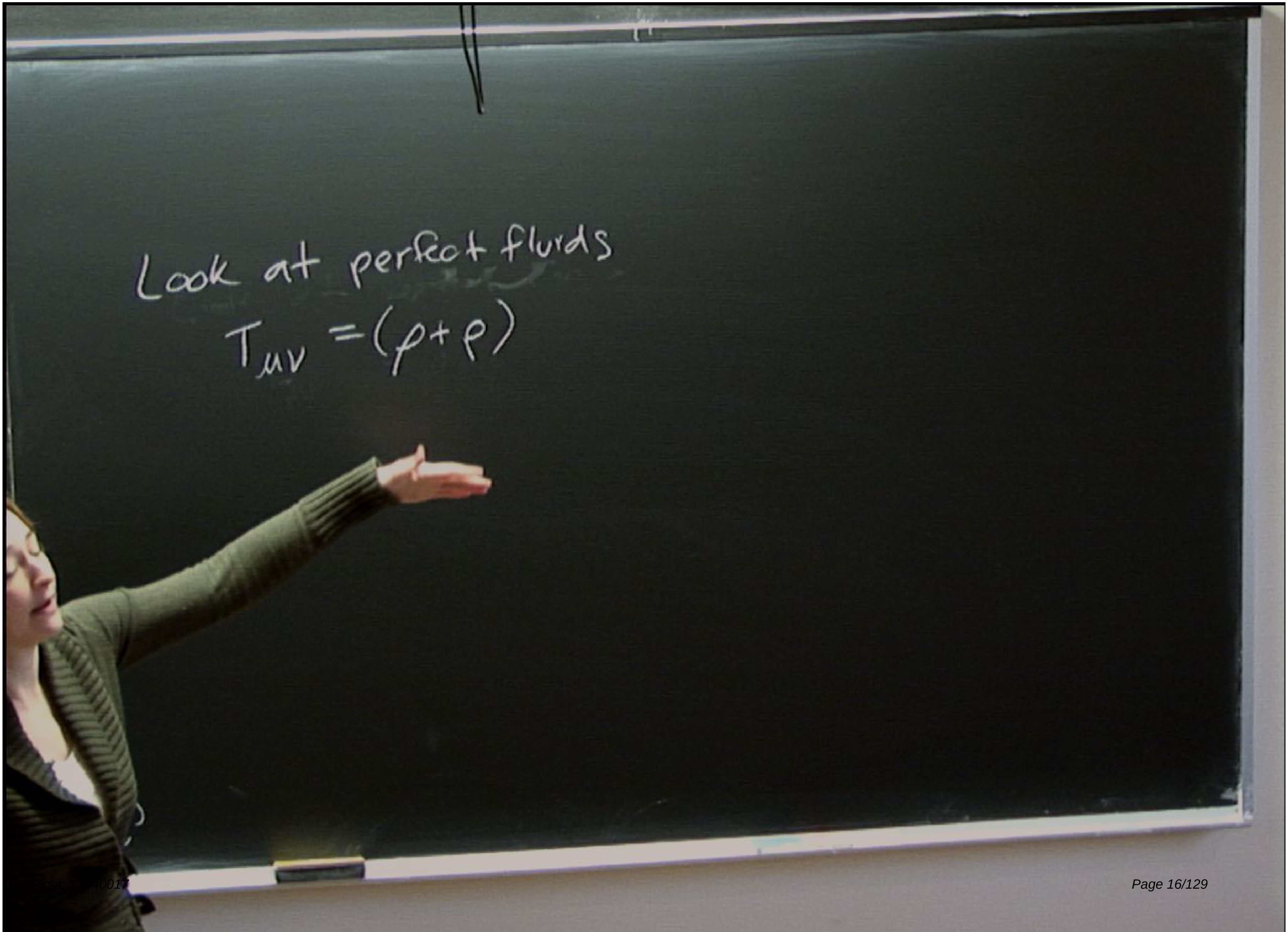
Null energy condition (NEC)

More generally

We can find geometries that are "weird" [acausal? Wormholes?]


Digression on $\dot{H} \leq 0$
Last time was
$\rho + p \geq 0 \Rightarrow \dot{H} \leq 0$
Null energy condition (NEC)
More generally
We can find geometries that
are "weird" [acausal? Wormholes?]
↳ can we make those with "realistic" matter?

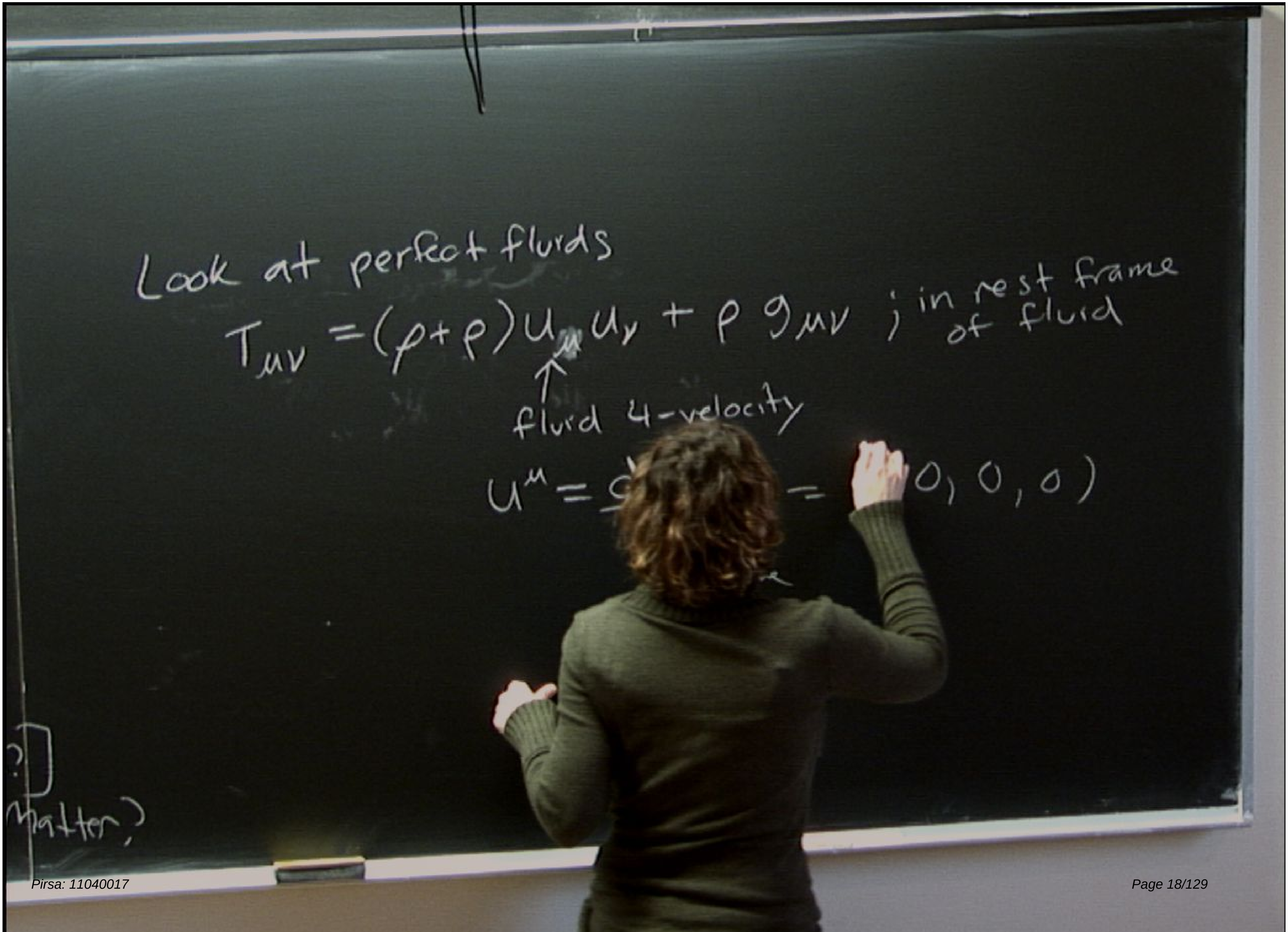

Look at perfect fluids

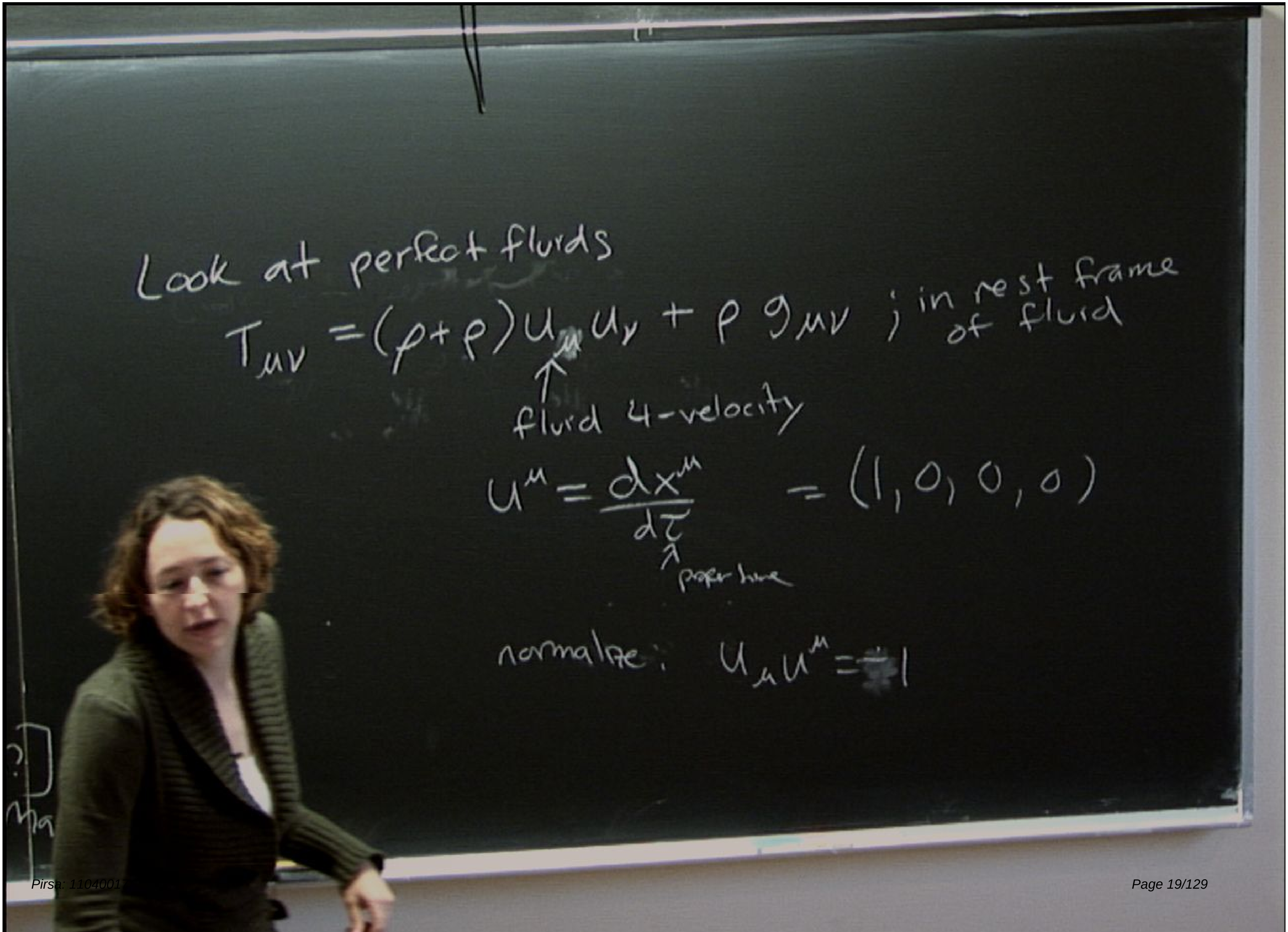

Look at perfect fluids
$T_{\mu\nu} = (\rho + p)$

Look at perfect fluids

$$T_{\mu\nu} = (\rho + p) u_\mu u_\nu + p\, g_{\mu\nu} \quad ; \text{ in rest frame of fluid}$$

$\uparrow$ fluid 4-velocity


Look at perfect fluids
$T_{\mu\nu} = (\rho + p) u_\mu u_\nu + p\, g_{\mu\nu}$; in rest frame of fluid
fluid 4-velocity
$u^\mu = $ … $ = (\ , 0, 0, 0)$
matter?


Look at perfect fluids
$T_{\mu\nu} = (\rho + p) u_\mu u_\nu + p\, g_{\mu\nu}$; in rest frame of fluid
fluid 4-velocity
$u^\mu = \frac{dx^\mu}{d\tau} = (1, 0, 0, 0)$
proper time
normalize: $u_\mu u^\mu = -1$

Look at perfect fluids

$T_{\mu\nu} = (\rho + p) u_\mu u_\nu + p\, g_{\mu\nu}$; in rest frame of fluid

fluid 4-velocity

$u^\mu = \frac{dx^\mu}{d\tau} = (1, 0, 0, 0)$

proper time

normalize: $u_\mu u^\mu = -1$

?

Matter?

Look at perfect fluids

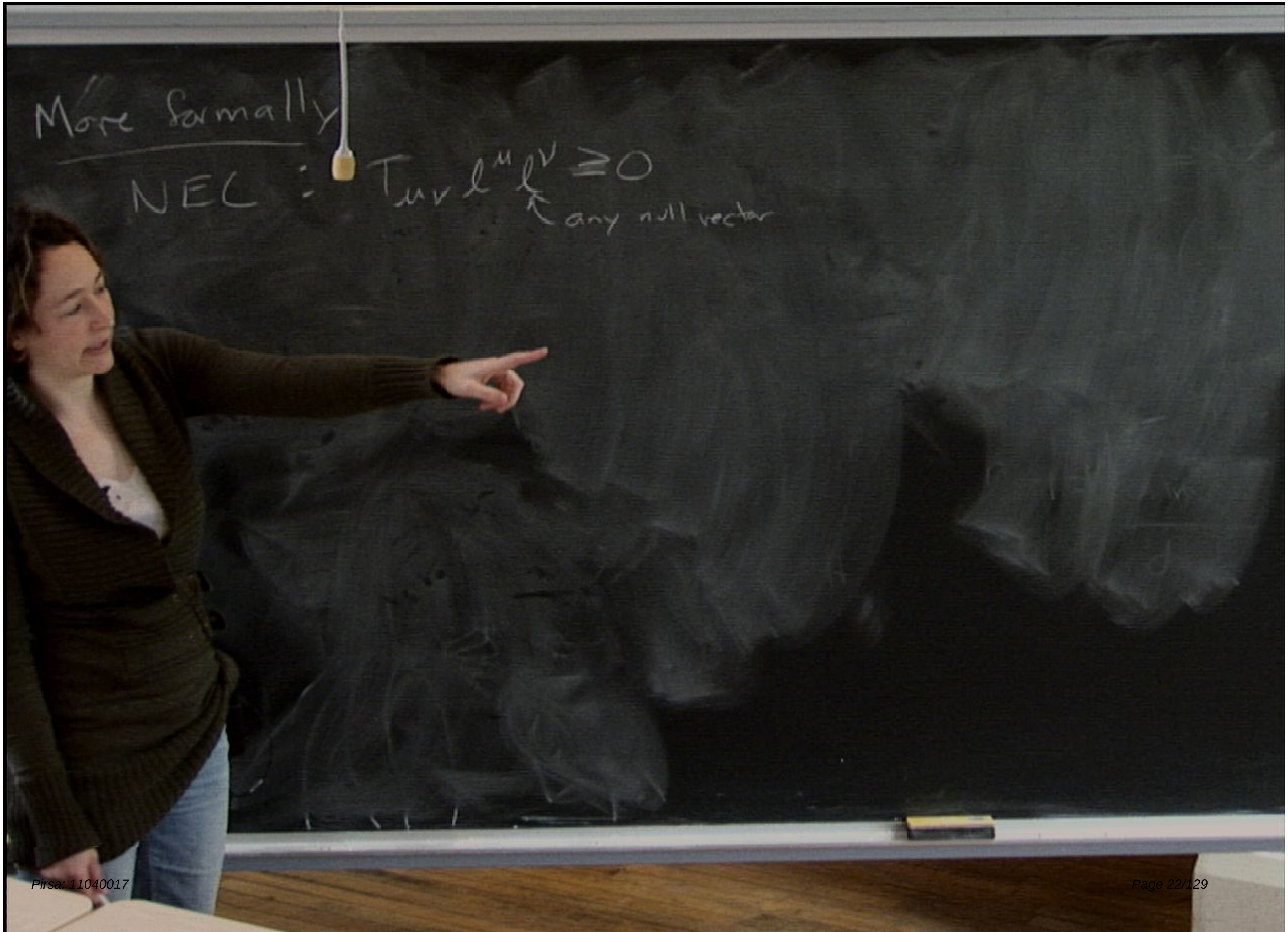
$$\boxed{T_{\mu\nu} = (\rho + p)\, u_\mu u_\nu + p\, g_{\mu\nu}} \; ; \text{ in rest frame of fluid}$$

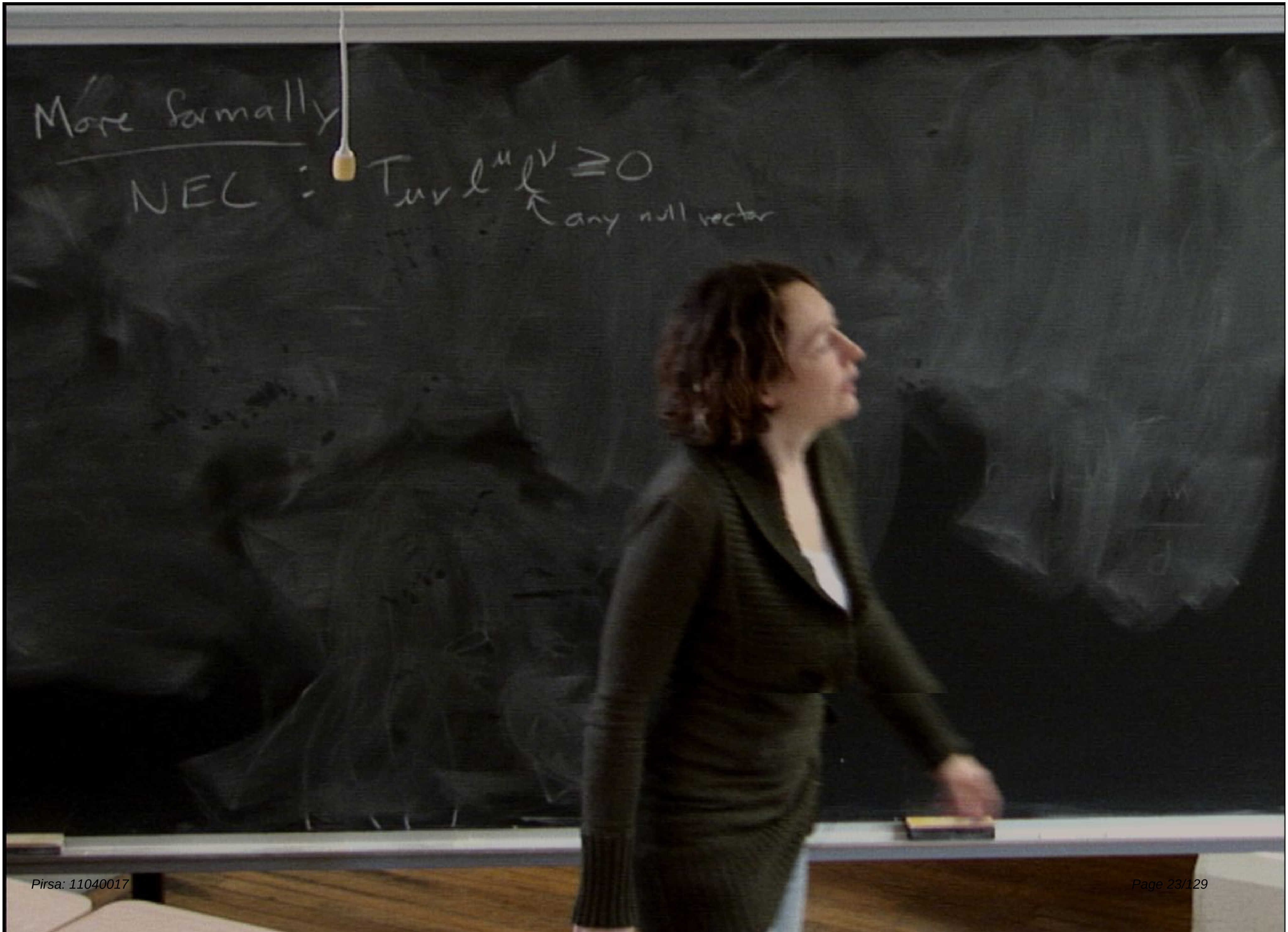
u_μ ↑ fluid 4-velocity

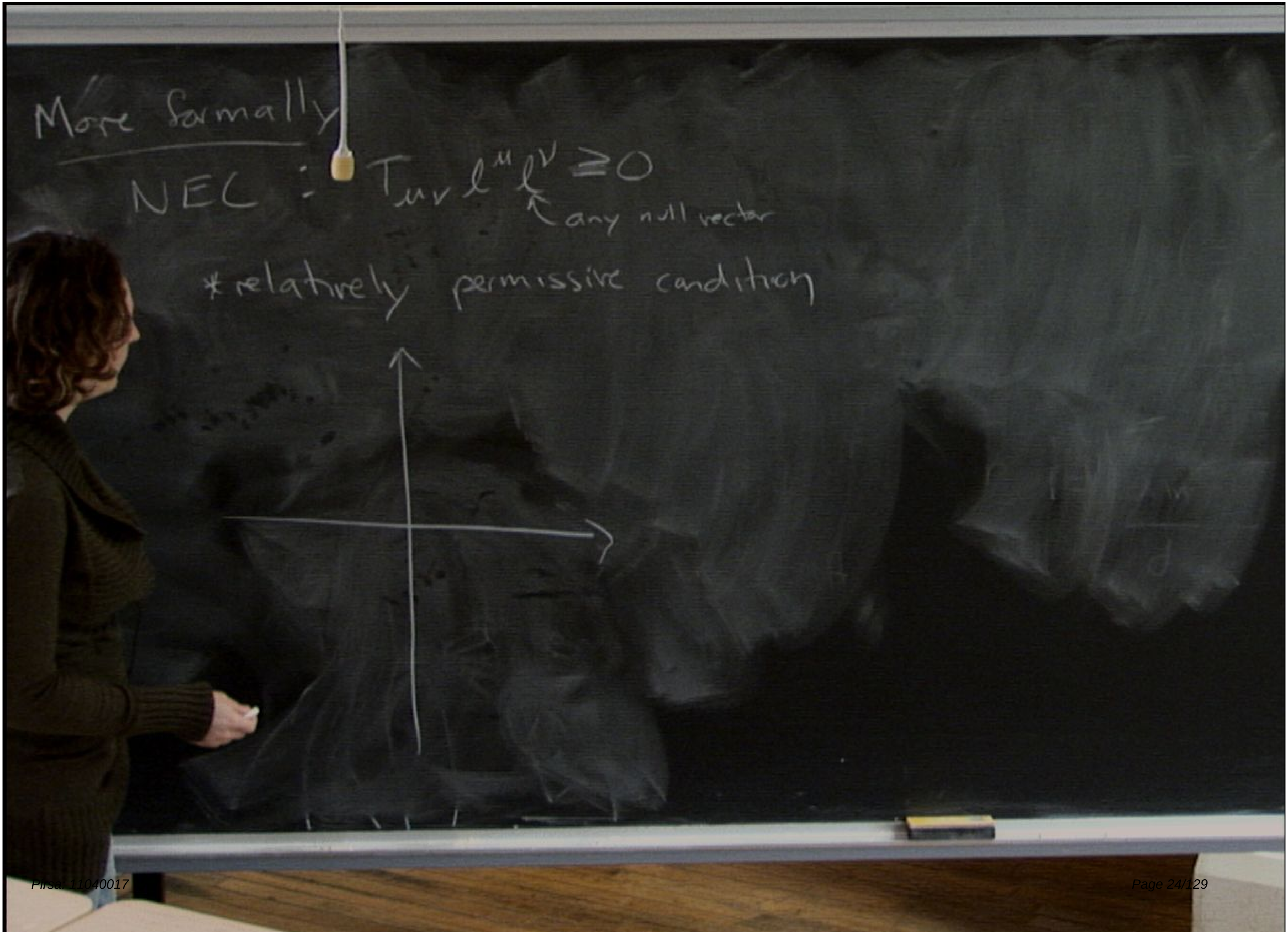
$$u^\mu = \frac{dx^\mu}{d\tau} = (1, 0, 0, 0)$$

τ ↑ proper time

normalize: $u_\mu u^\mu = -1$


More formally
NEC : $T_{\mu\nu} l^\mu l^\nu \geq 0$
any null vector

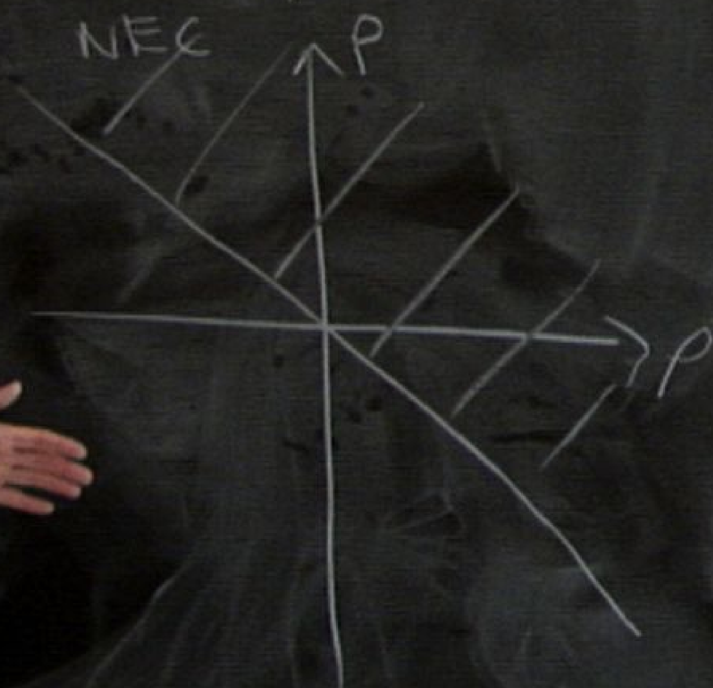

More formally
NEC : $T_{\mu\nu} l^\mu l^\nu \geq 0$
any null vector


More formally
NEC : $T_{\mu\nu} l^\mu l^\nu \geq 0$
any null vector
* relatively permissive condition

More formally

NEC : $T_{\mu\nu} \ell^\mu \ell^\nu \geq 0$ ← any null vector

* relatively permissive condition



Digression on $\dot{H} \le 0$

Last time was

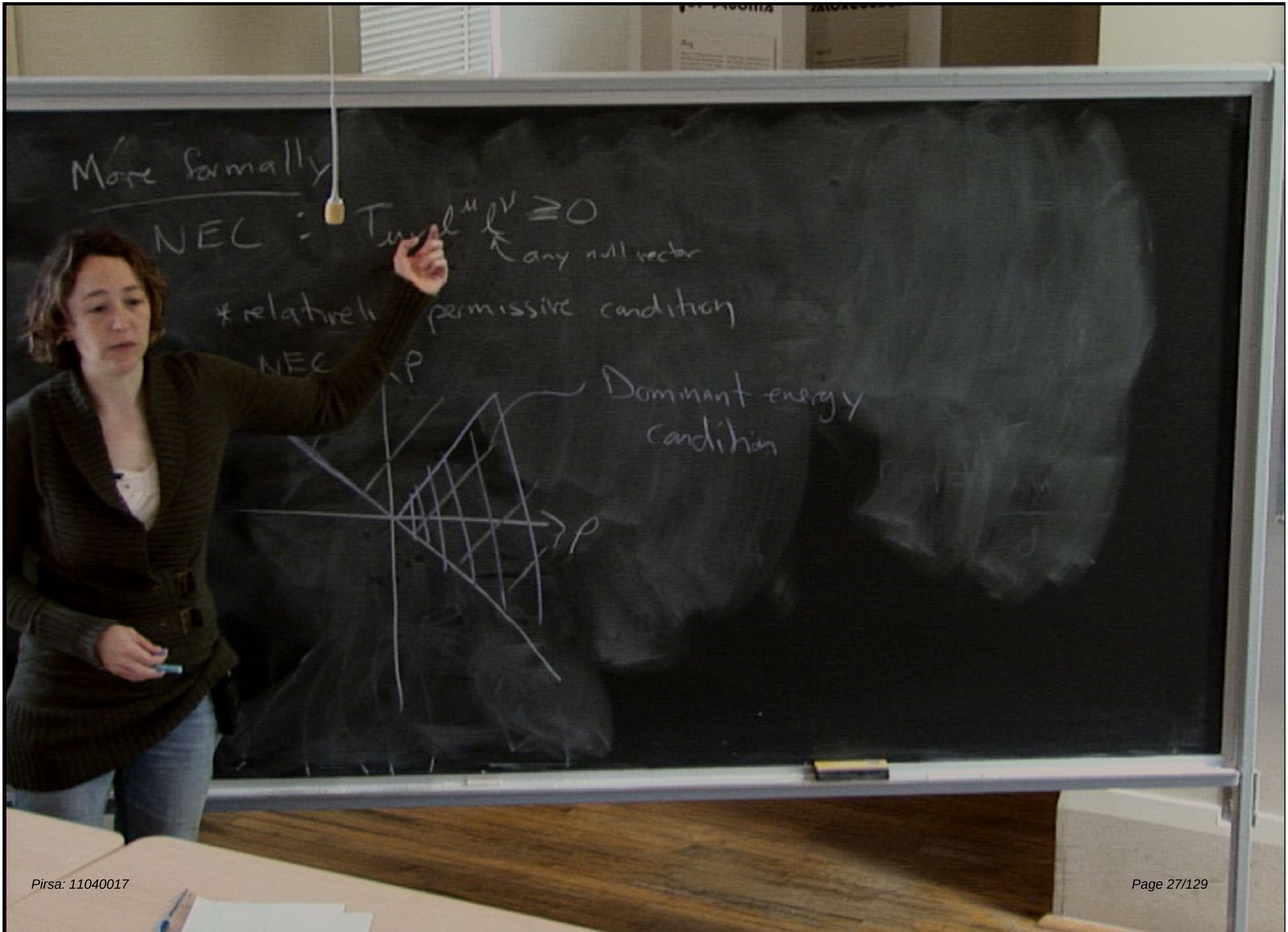
$$\rho + p \geq 0 \Rightarrow \dot{H} \le 0$$

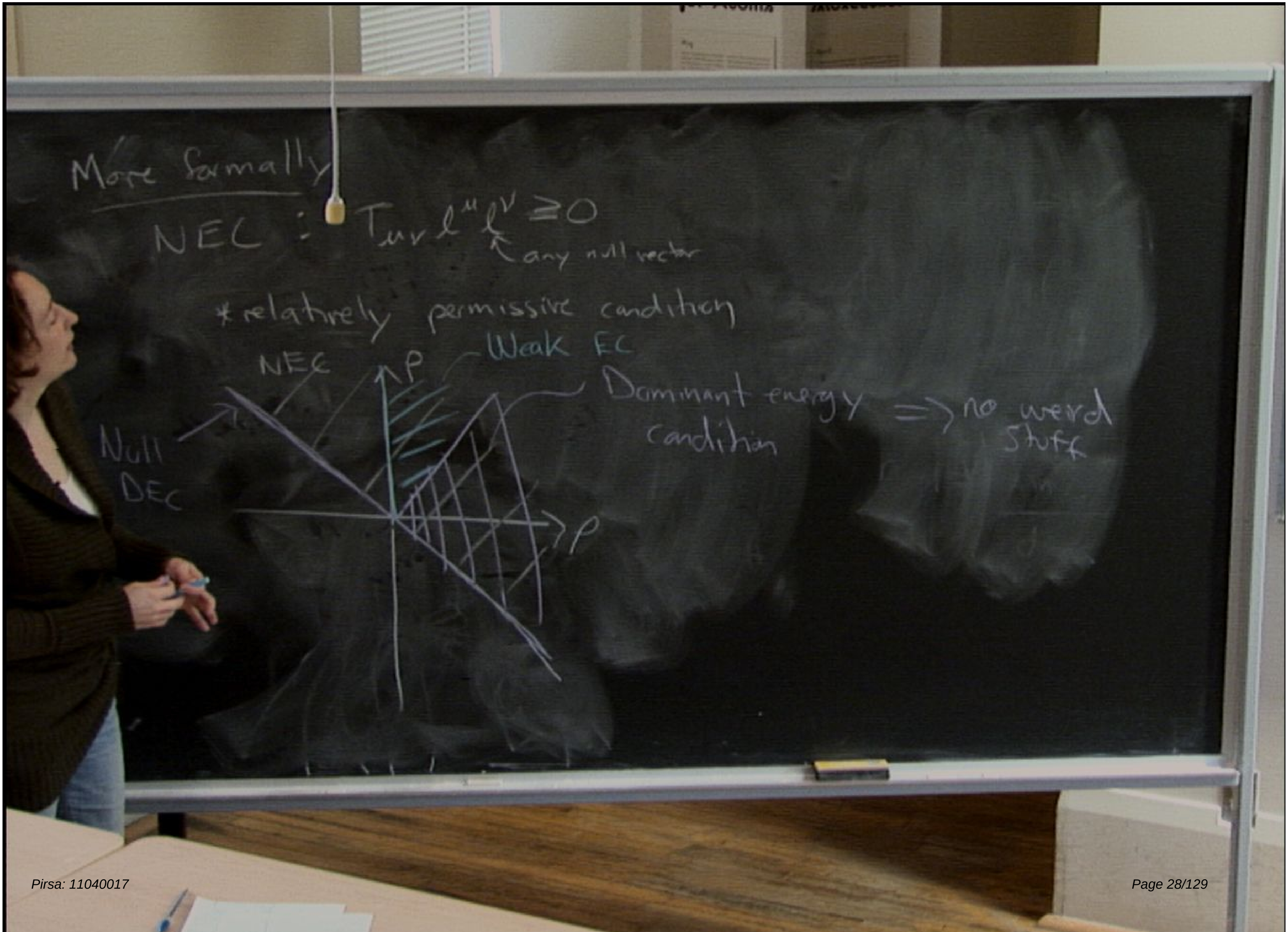
Null energy condition (NEC)

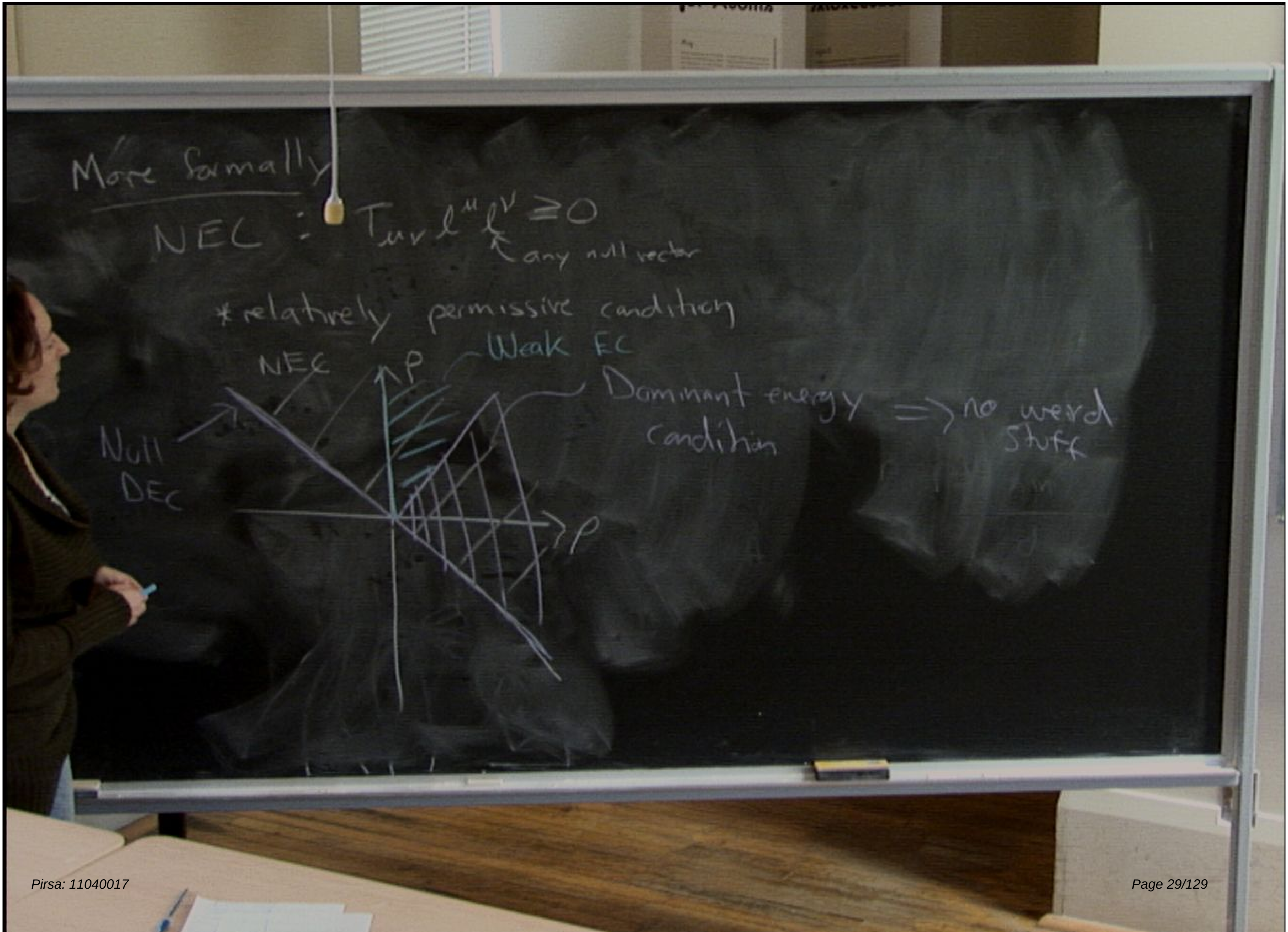
More generally

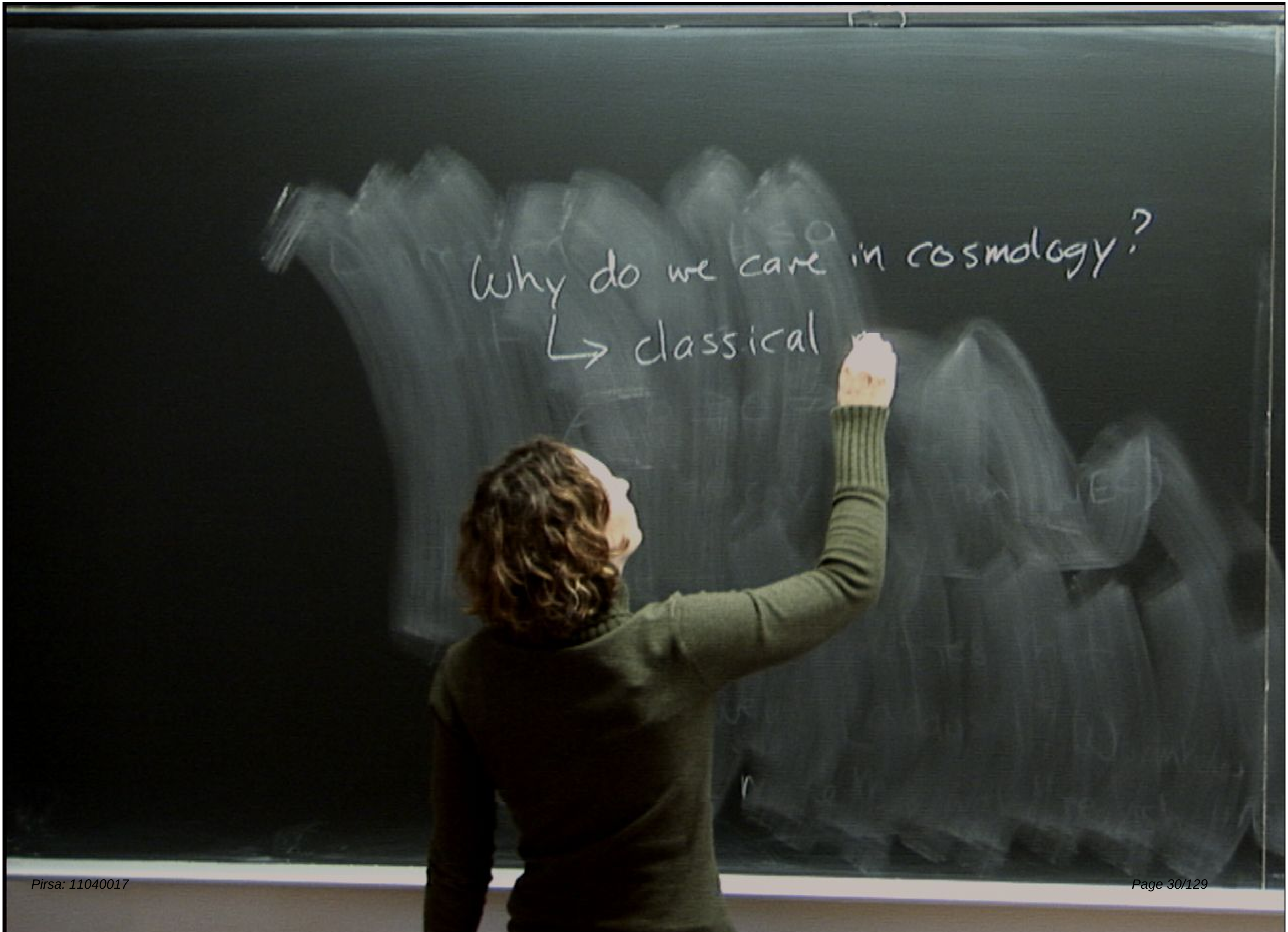
We can find geometries that are "weird" [acausal? Wormholes?]

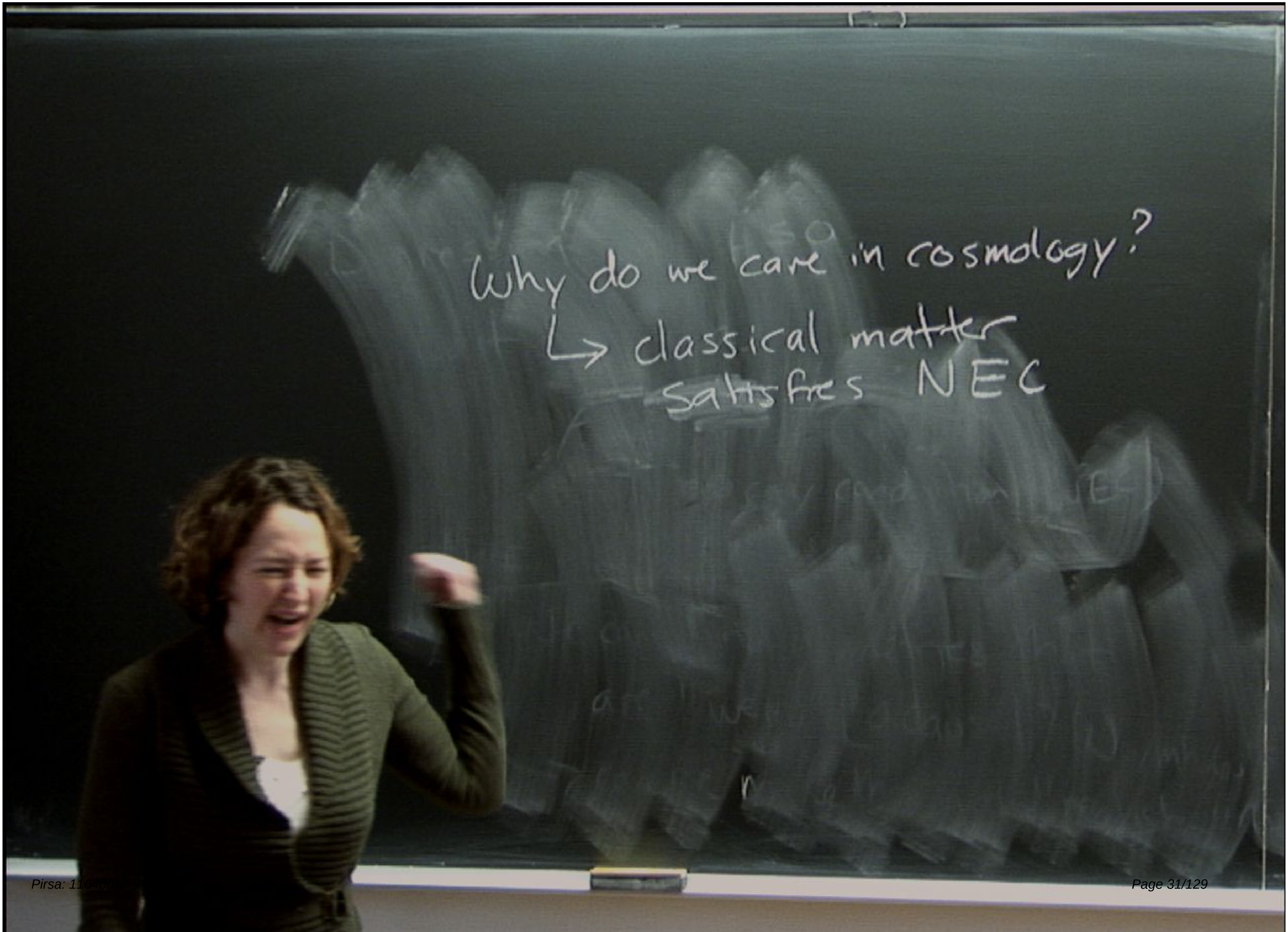
→ can we make those with "realistic" ma

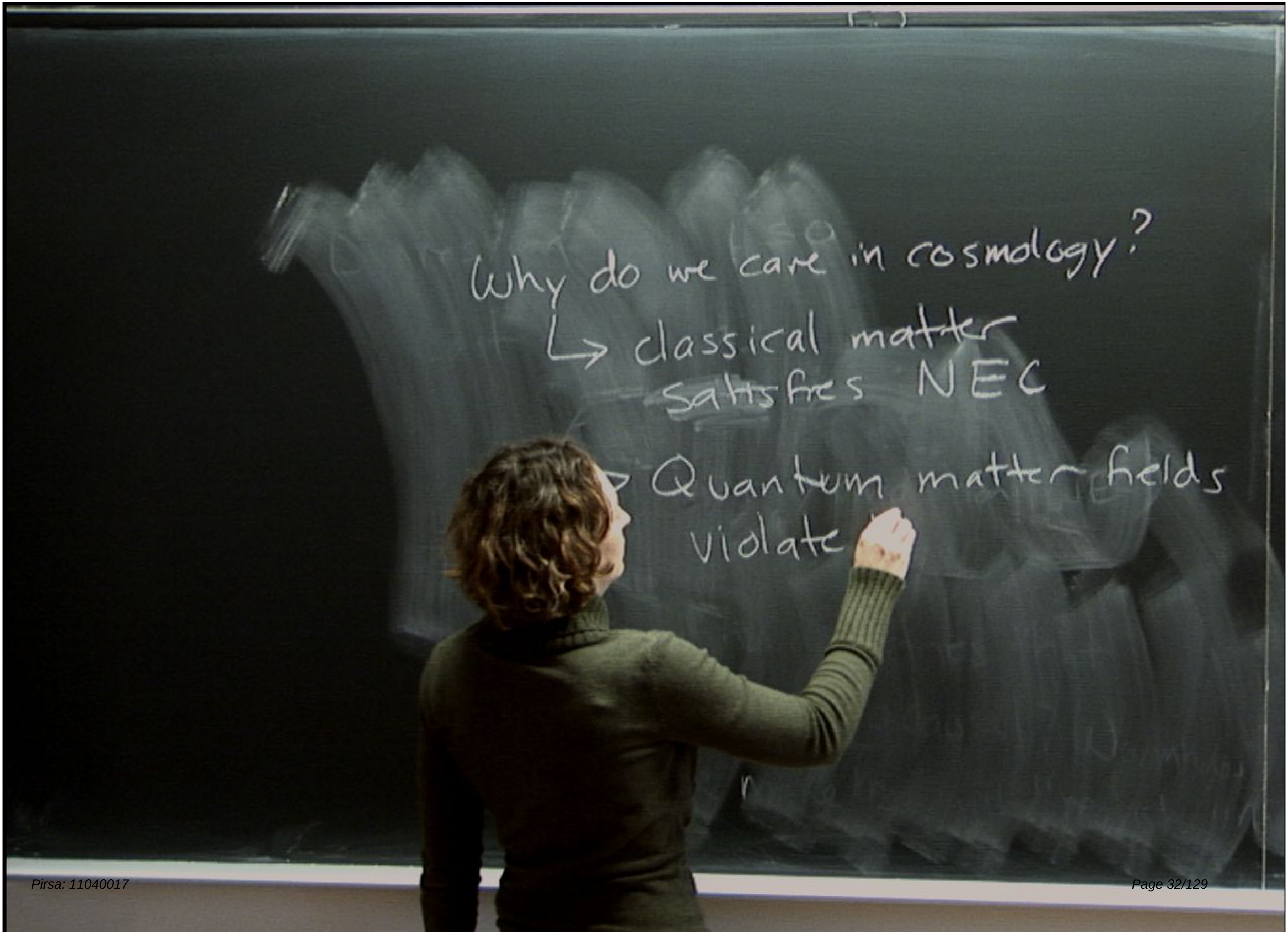

More formally
NEC : $T_{\mu\nu} l^{\mu} l^{\nu} \geq 0$
any null vector
* relatively permissive condition
Dominant energy condition
P
ρ

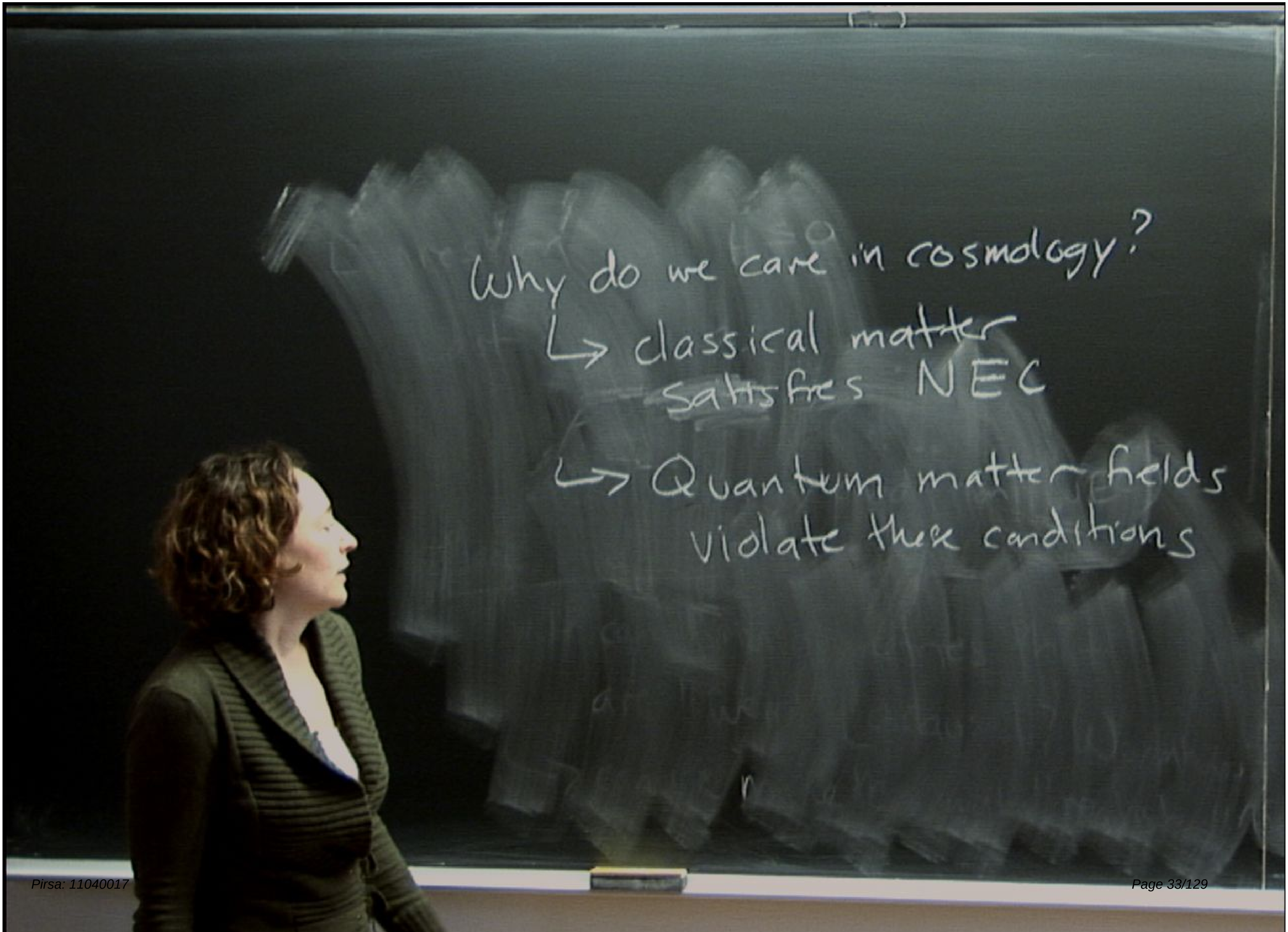

More formally
NEC : $T_{\mu\nu} l^\mu l^\nu \geq 0$
any null vector
* relatively permissive condition
Weak EC
NEC
ρ
Dominant energy condition
⇒ no weird stuff
Null DEC
p

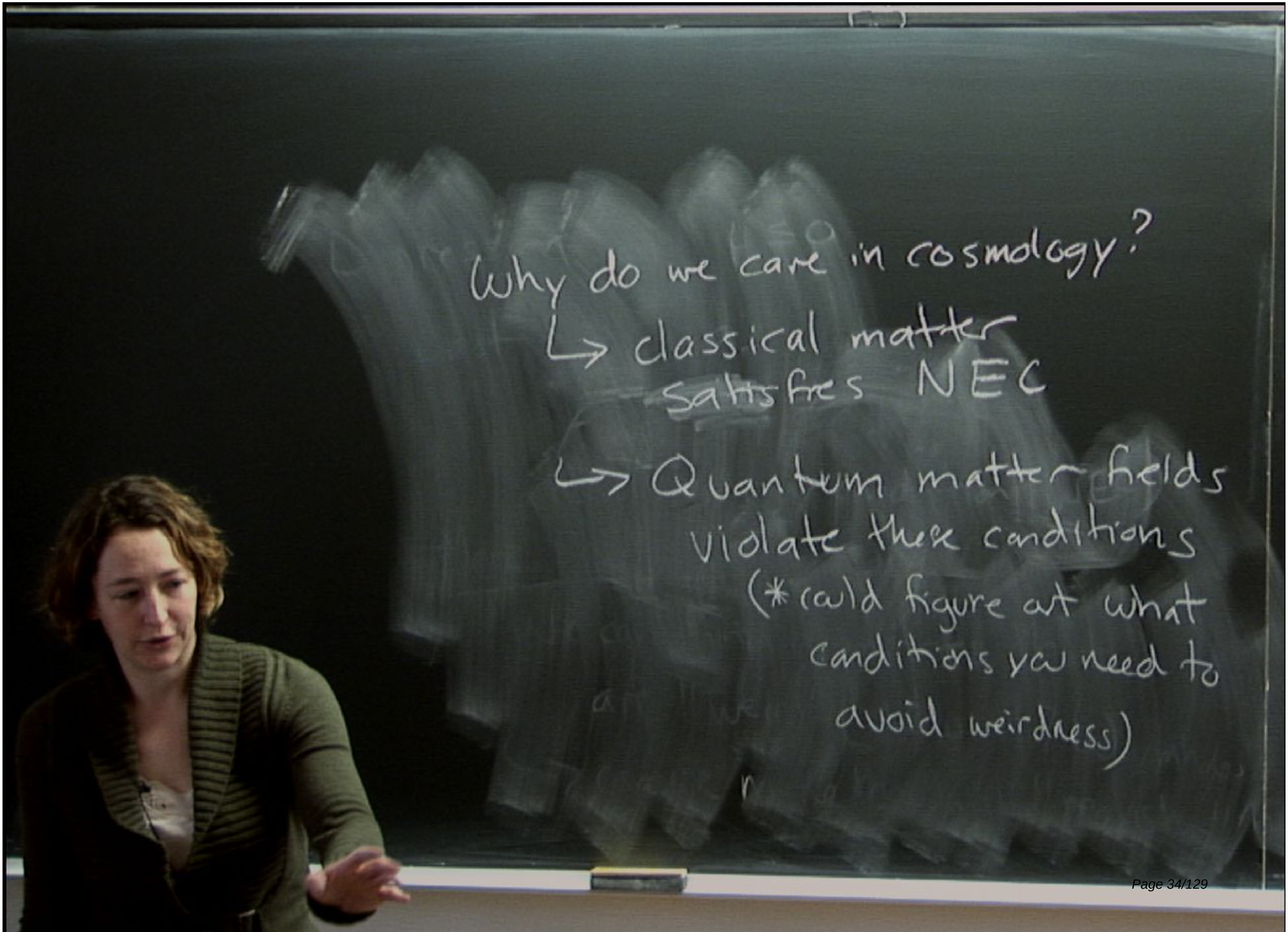

More formally
NEC : $T_{\mu\nu} l^\mu l^\nu \geq 0$
any null vector
* relatively permissive condition
Weak EC
NEC
Null DEC
Dominant energy condition ⟹ no weird stuff
ρ
p


Why do we care in cosmology?
↳ classical


Why do we care in cosmology?
↳ classical matter
satisfies NEC


Why do we care in cosmology?
classical matter
satisfies NEC
Quantum matter fields
violate


Why do we care in cosmology?
↳ classical matter
satisfies NEC
↳ Quantum matter fields
violate these conditions


Why do we care in cosmology?
↳ classical matter satisfies NEC
↳ Quantum matter fields violate these conditions
(* could figure out what conditions you need to avoid weirdness)

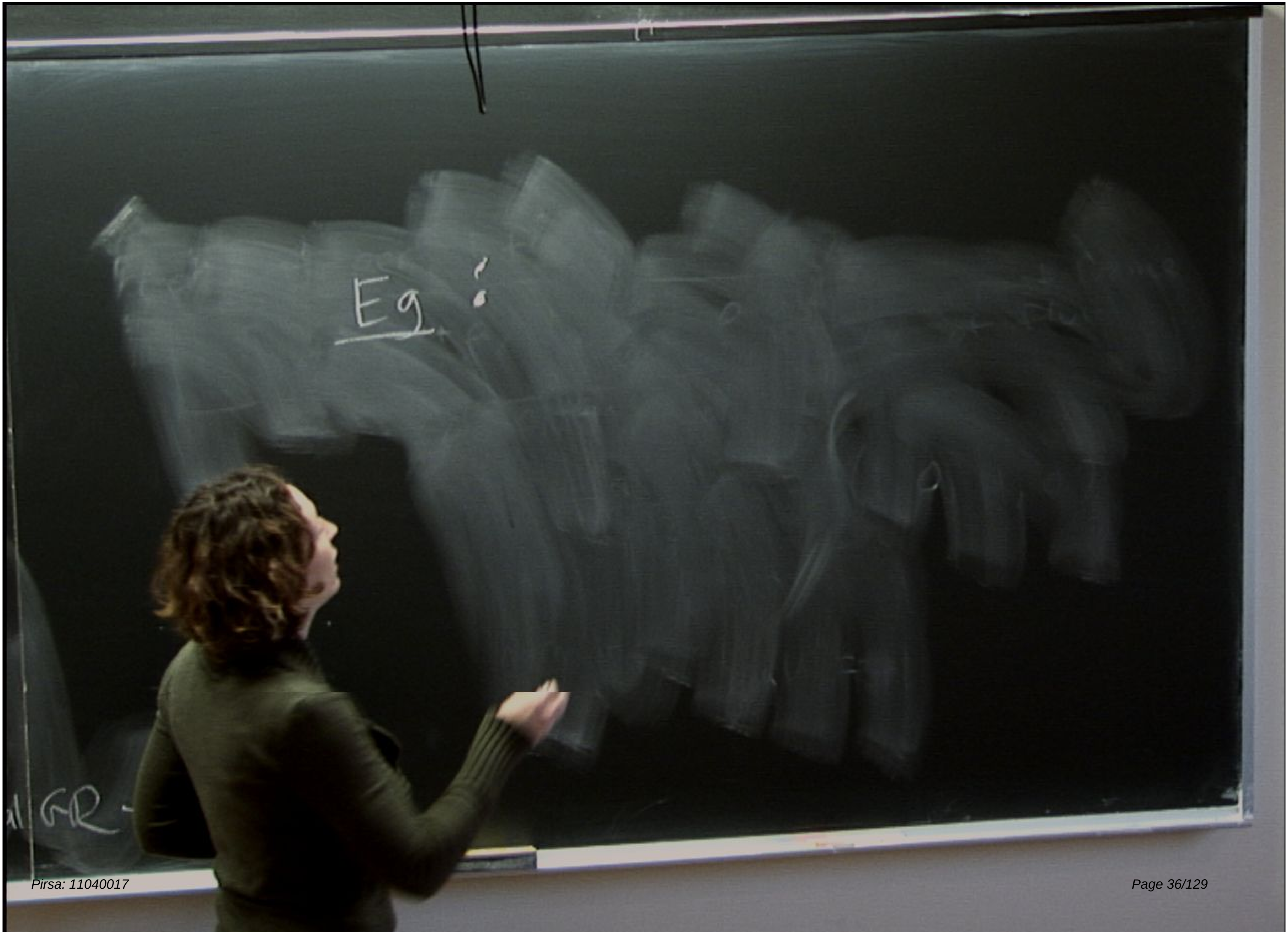
Why do we care in cosmology?

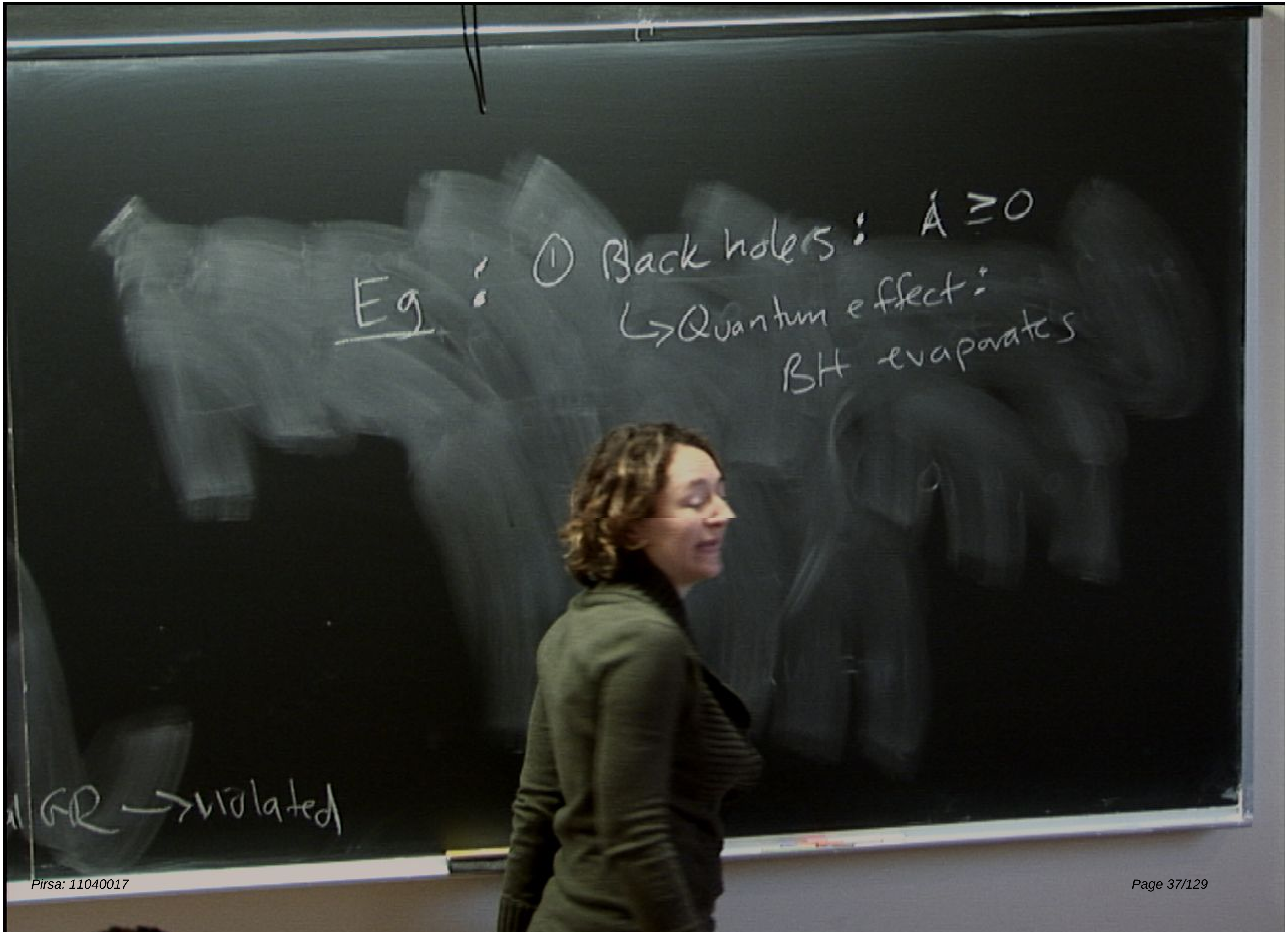
↳ classical matter satisfies NEC

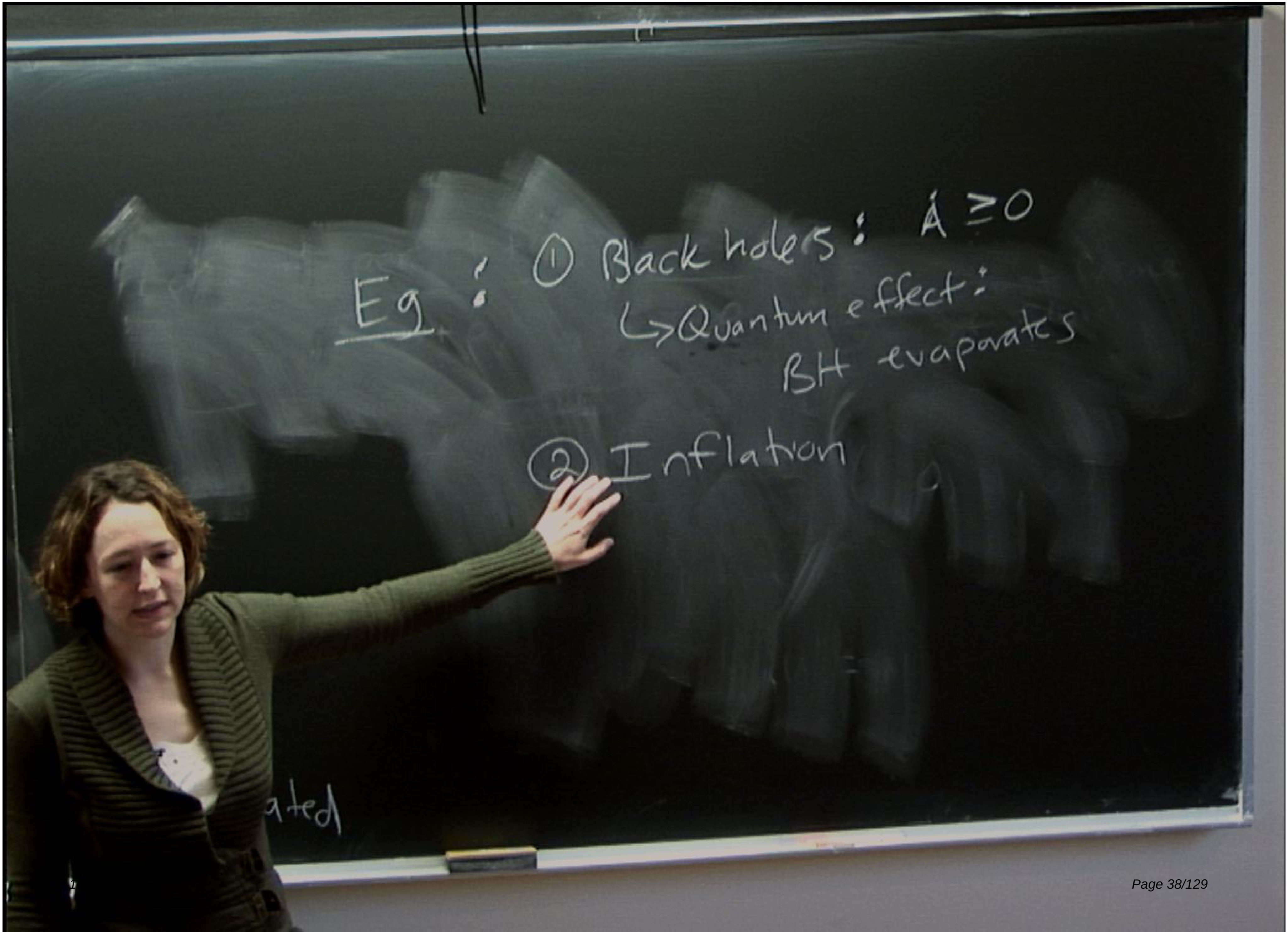
↳ Quantum matter fields violate these conditions

(* could figure out what conditions you need to avoid weirdness)

* results proved in classical GR → violated


Eg:
GR


Eg: ① Black holes: Ȧ ≥ 0
↳ Quantum effect:
BH evaporates
al GR → violated


Eg: ① Black holes: Ȧ ≥ 0
↳Quantum effect:
BH evaporates
② Inflation
ated

Eg: (1) Black holes: $\dot{A} \geq 0$

↳ Quantum effect: BH evaporates

(2) Inflation: stochastic eternal inflation

al GR → violated

Eg: ① Black holes: $\dot{A} \geq 0$

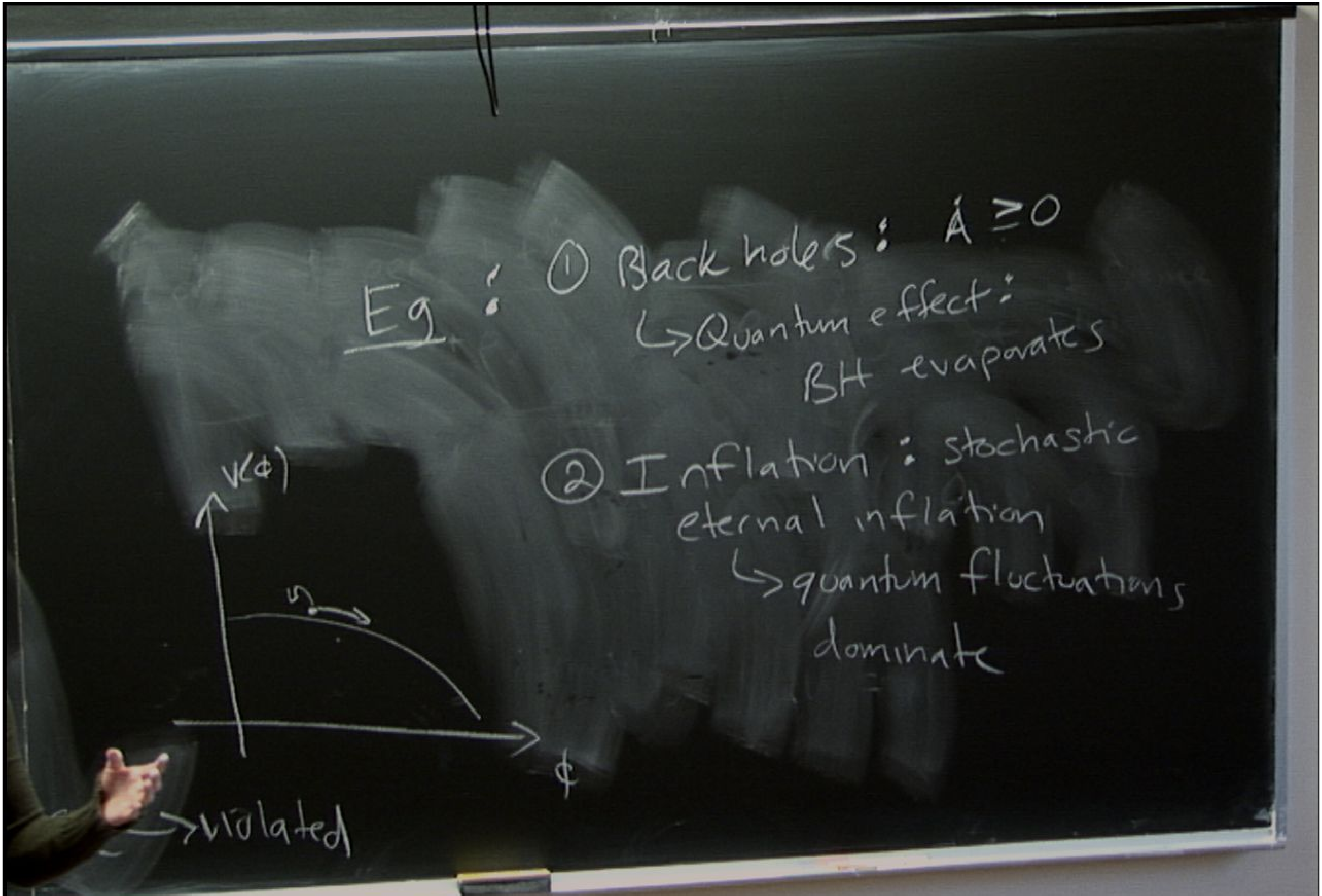
↳ Quantum effect:

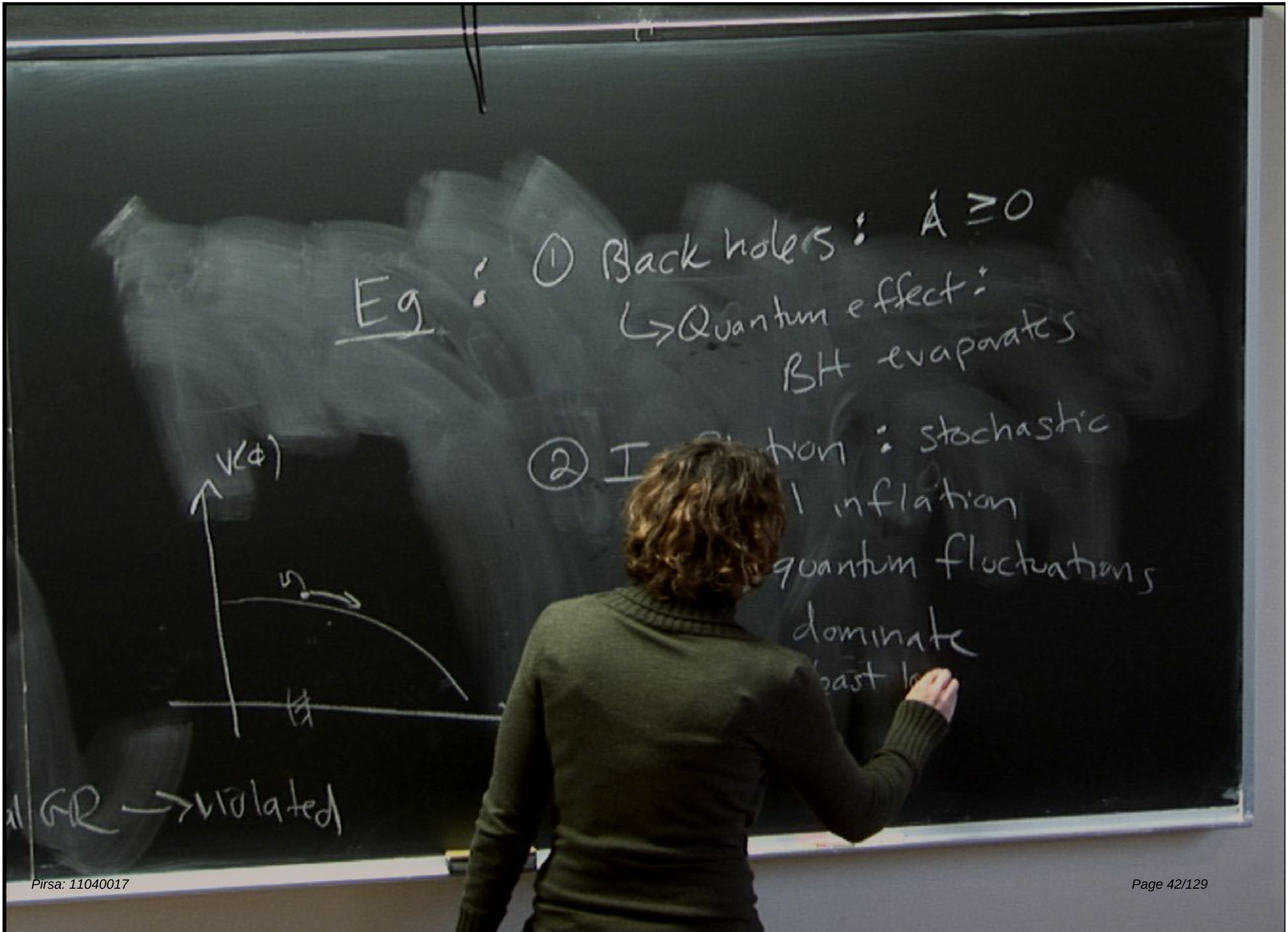
BH evaporates

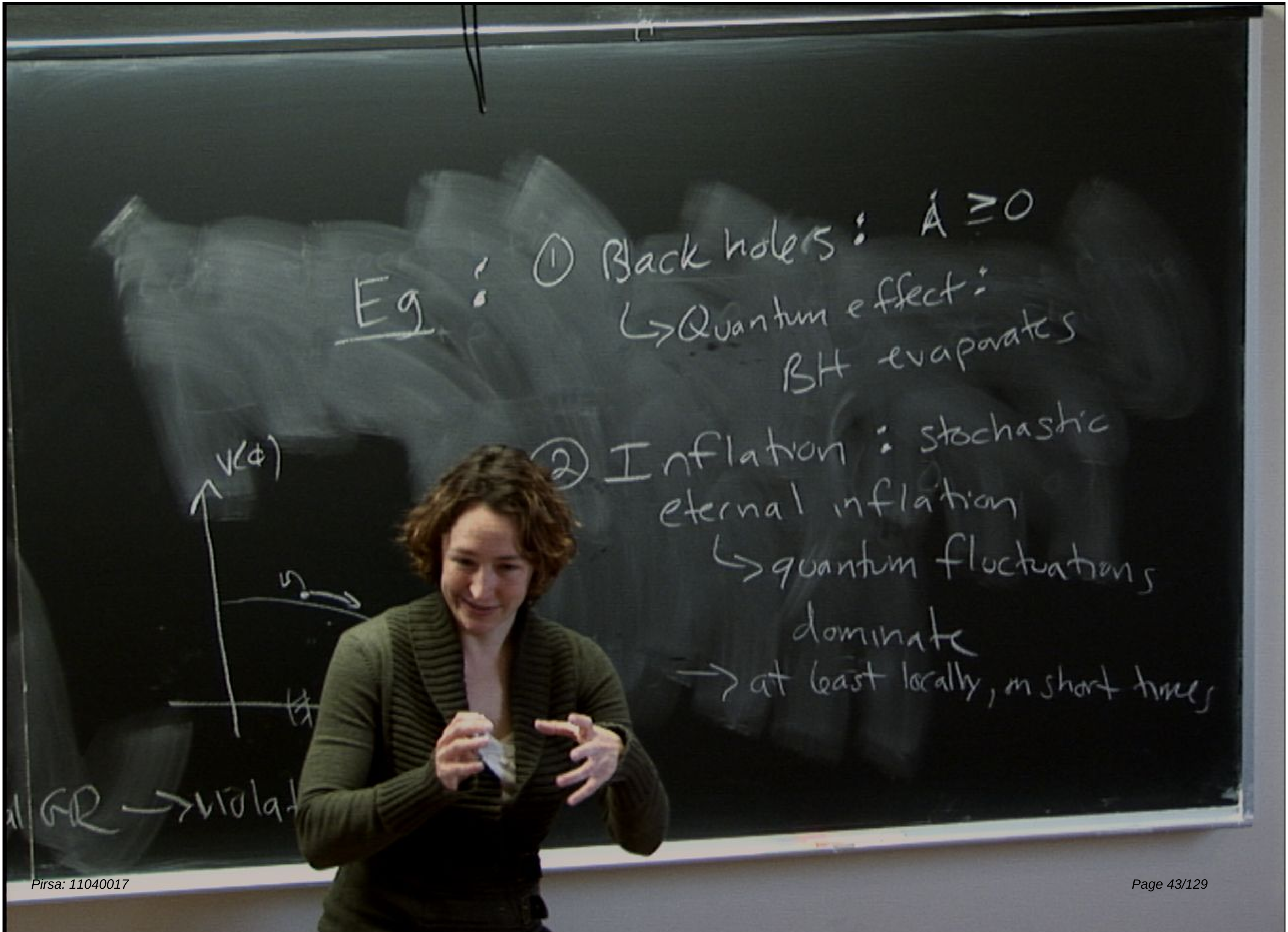
② Inflation: stochastic eternal inflation

↳ quantum fluctuations dominate

→ violated


Eg: ① Black holes: $\dot{A} \geq 0$
↳ Quantum effect:
BH evaporates
② Inflation: stochastic
eternal inflation
↳ quantum fluctuations
dominate
$V(\phi)$
ϕ
↳ violated


Eg:
① Black holes: $\dot{A} \geq 0$
↳ Quantum effect:
BH evaporates
② I…tion : stochastic
… inflation
quantum fluctuations
dominate
…ast …
$V(\phi)$
GR → violated


Eg: ① Black holes: Ȧ ≥ 0
↳ Quantum effect:
BH evaporates
② Inflation: stochastic
eternal inflation
↳ quantum fluctuations
dominate
→ at least locally, in short times
V(φ)

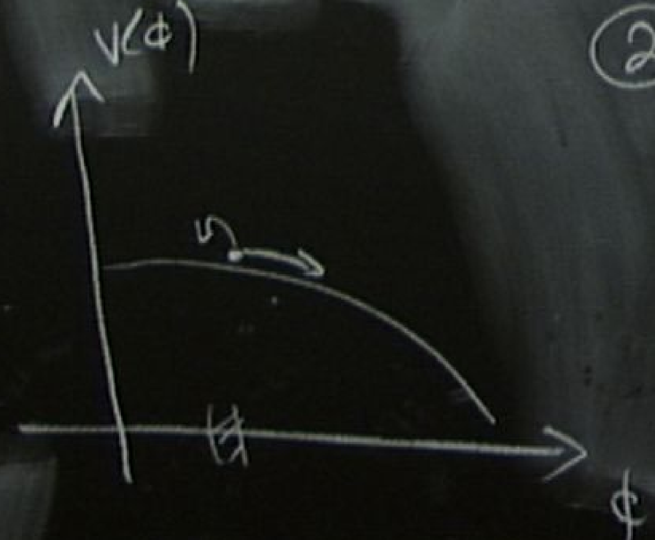
Eg: ① Black holes: $\dot{A} \geq 0$

↳ Quantum effect: BH evaporates

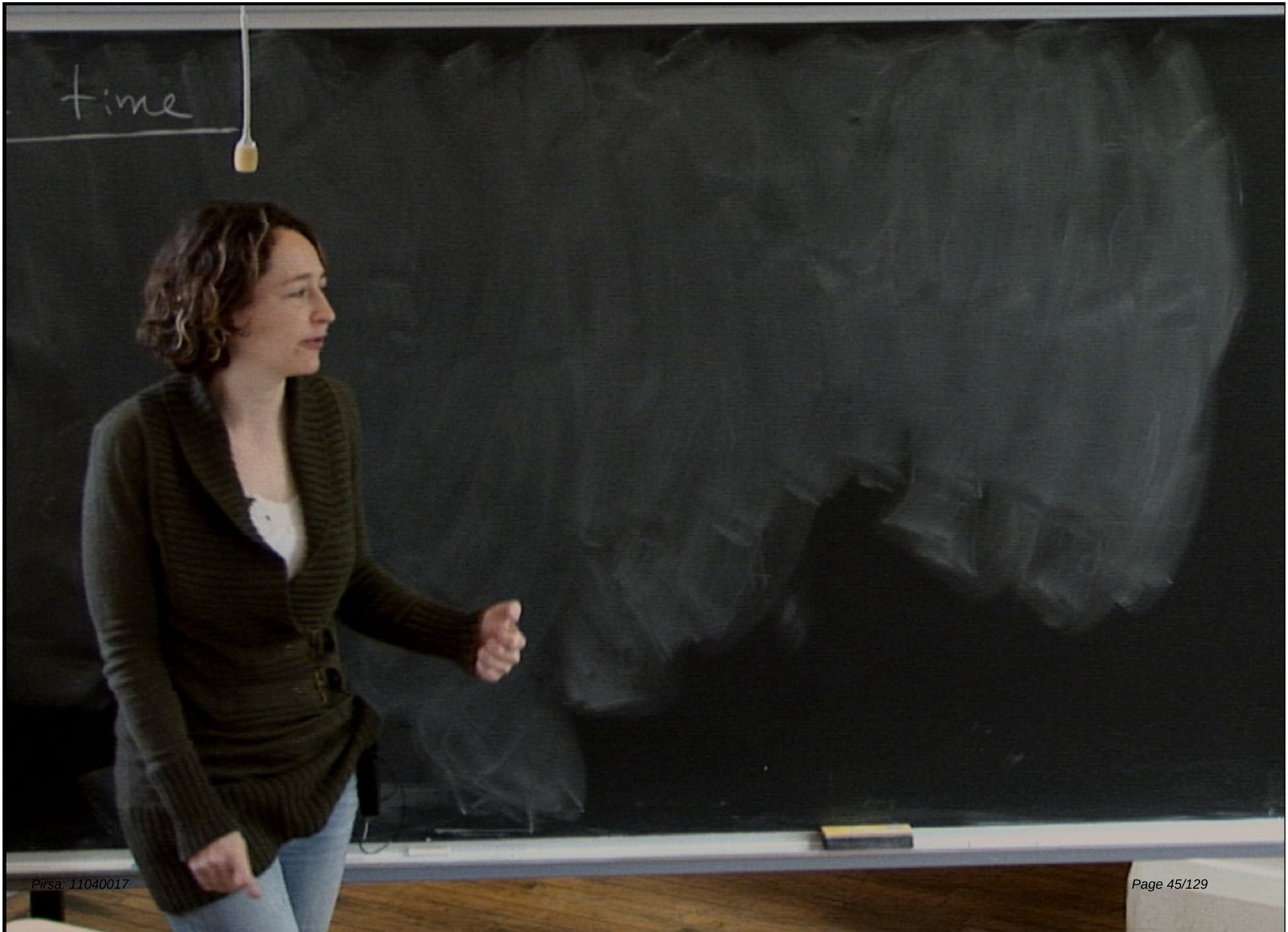
② Inflation: stochastic eternal inflation

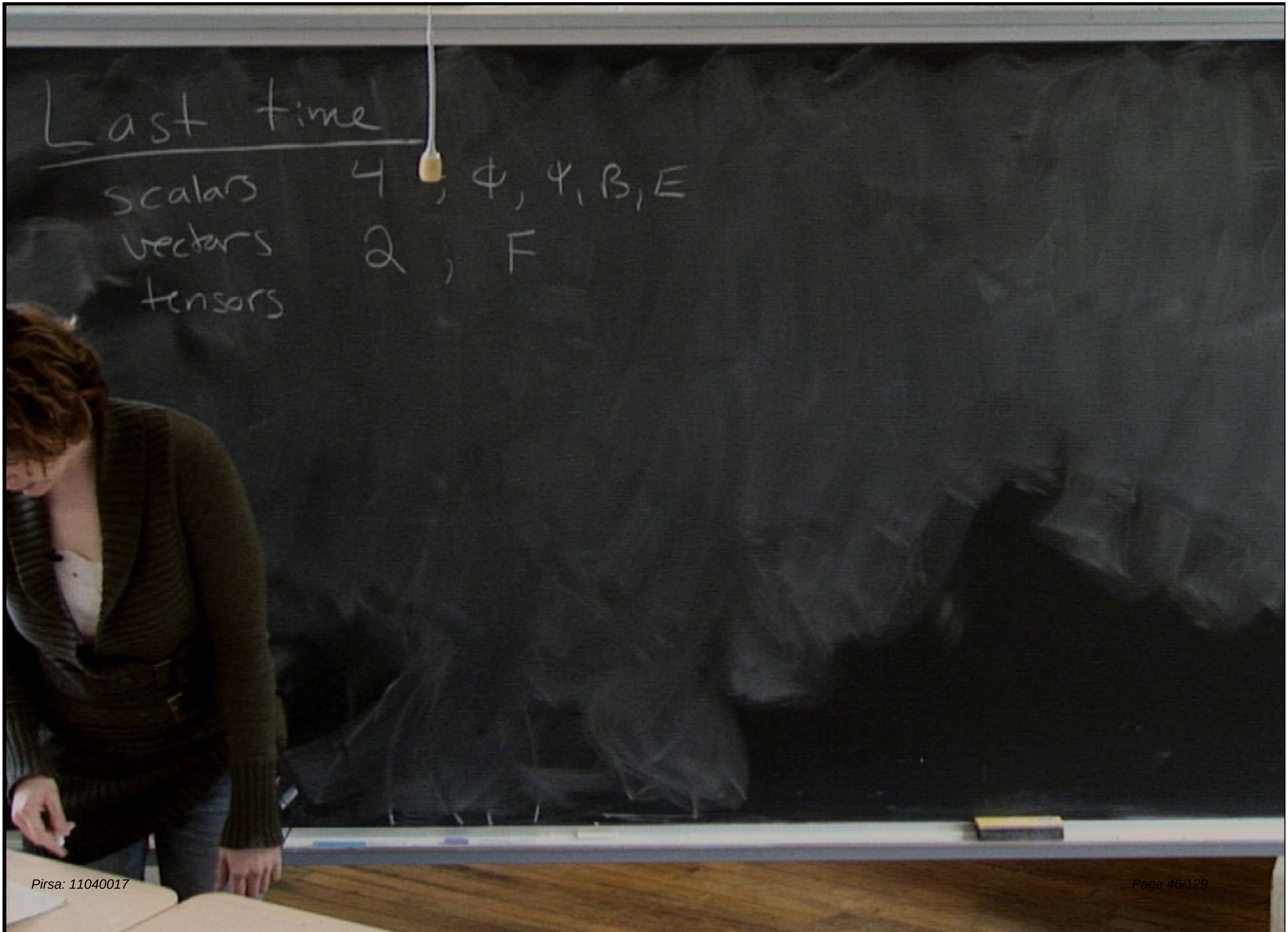
↳ quantum fluctuations dominate

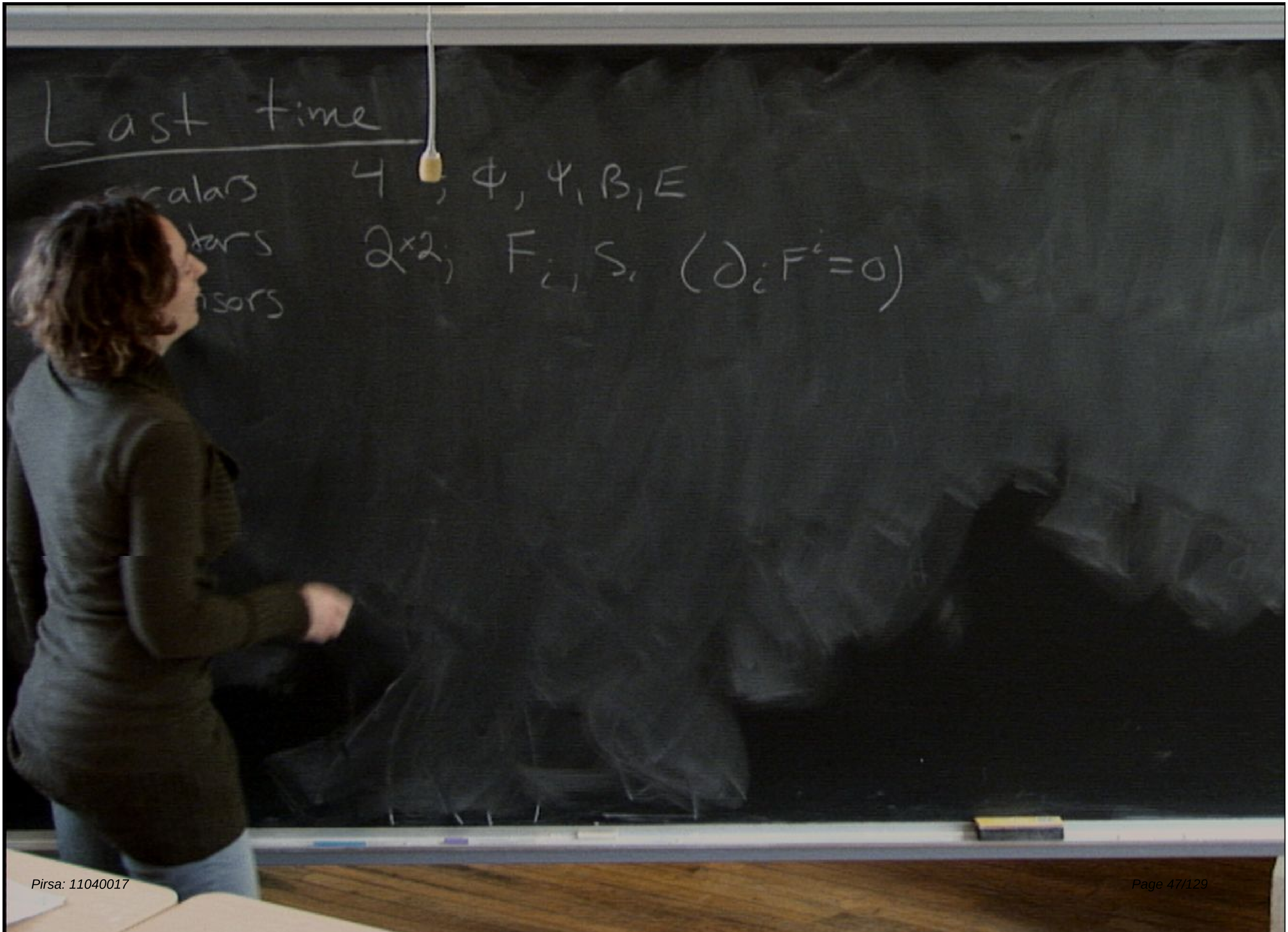
→ at least locally, on short times on Hubble scales $\dot{H} > 0$

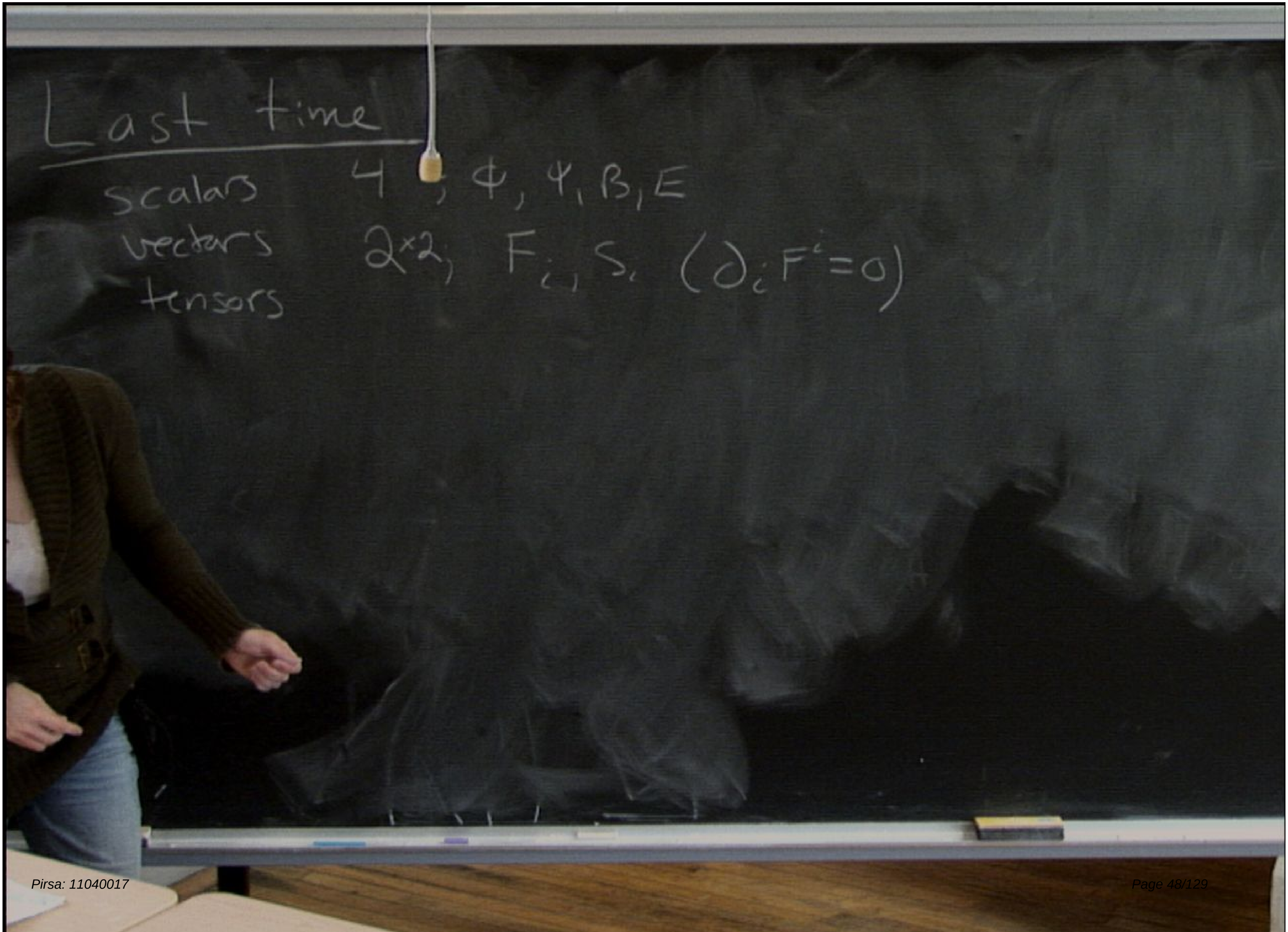


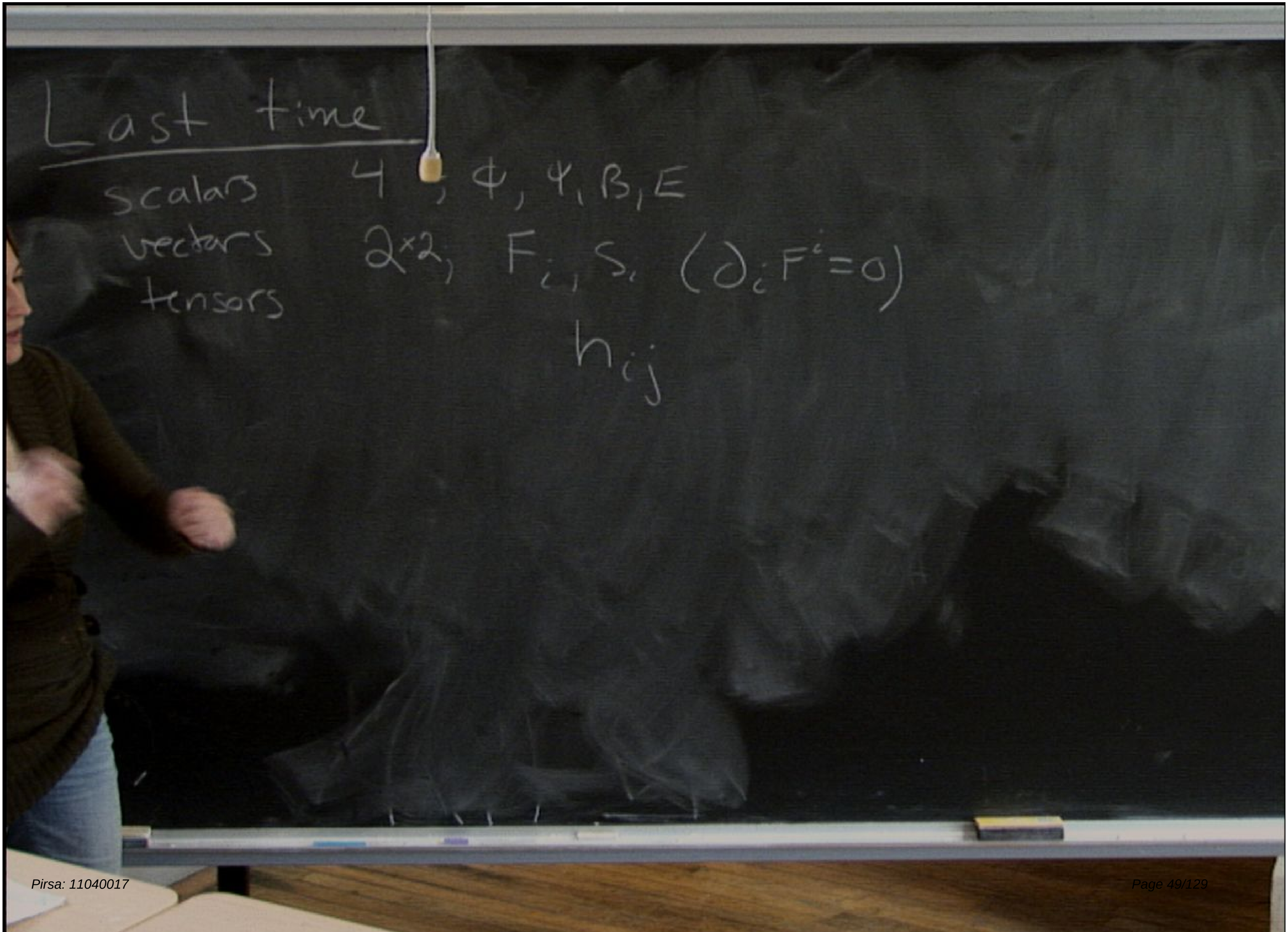
...al GR → violated

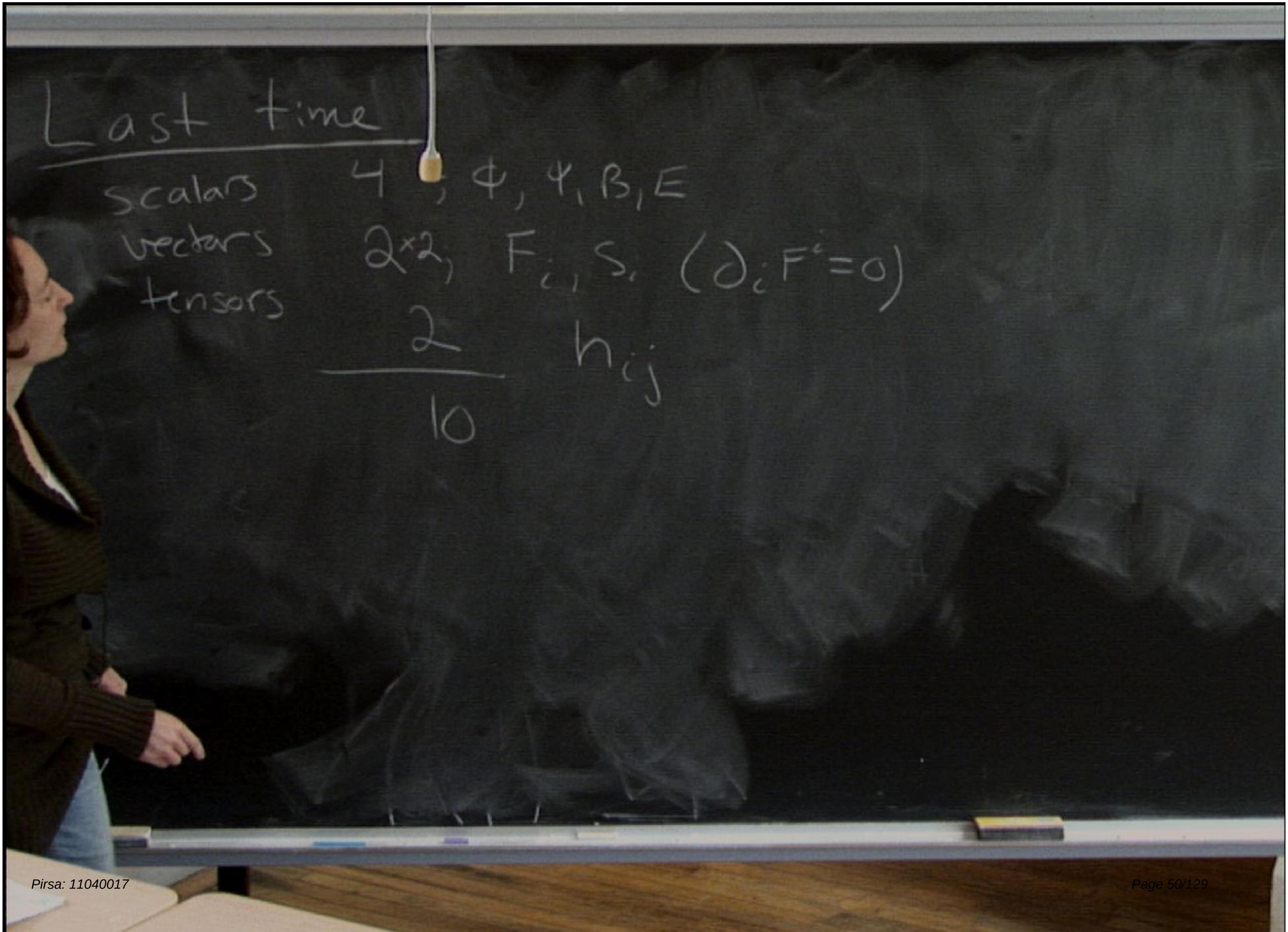

time

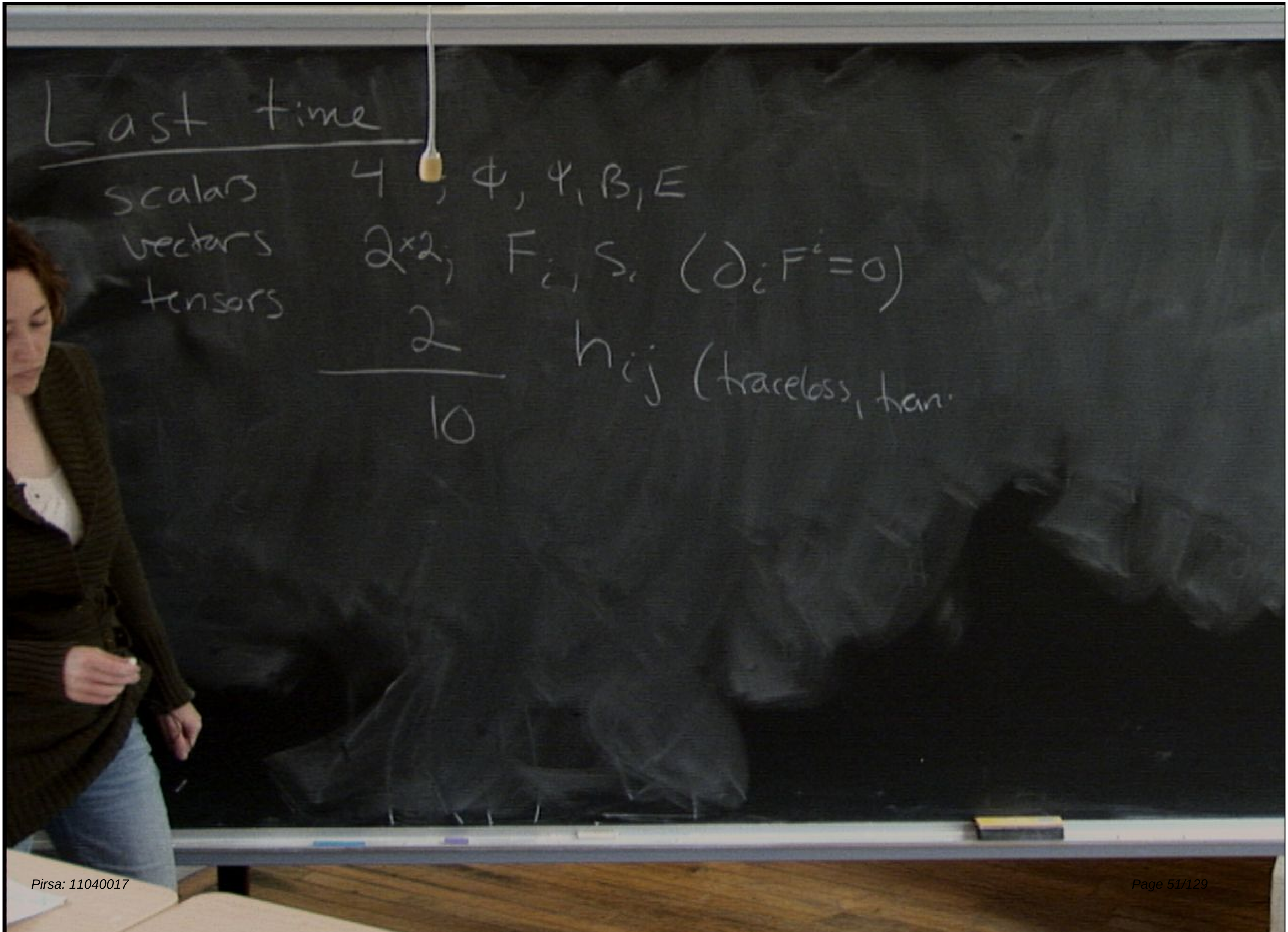

Last time
scalars 4 ; ϕ, ψ, B, E
vectors 2 ; F
tensors

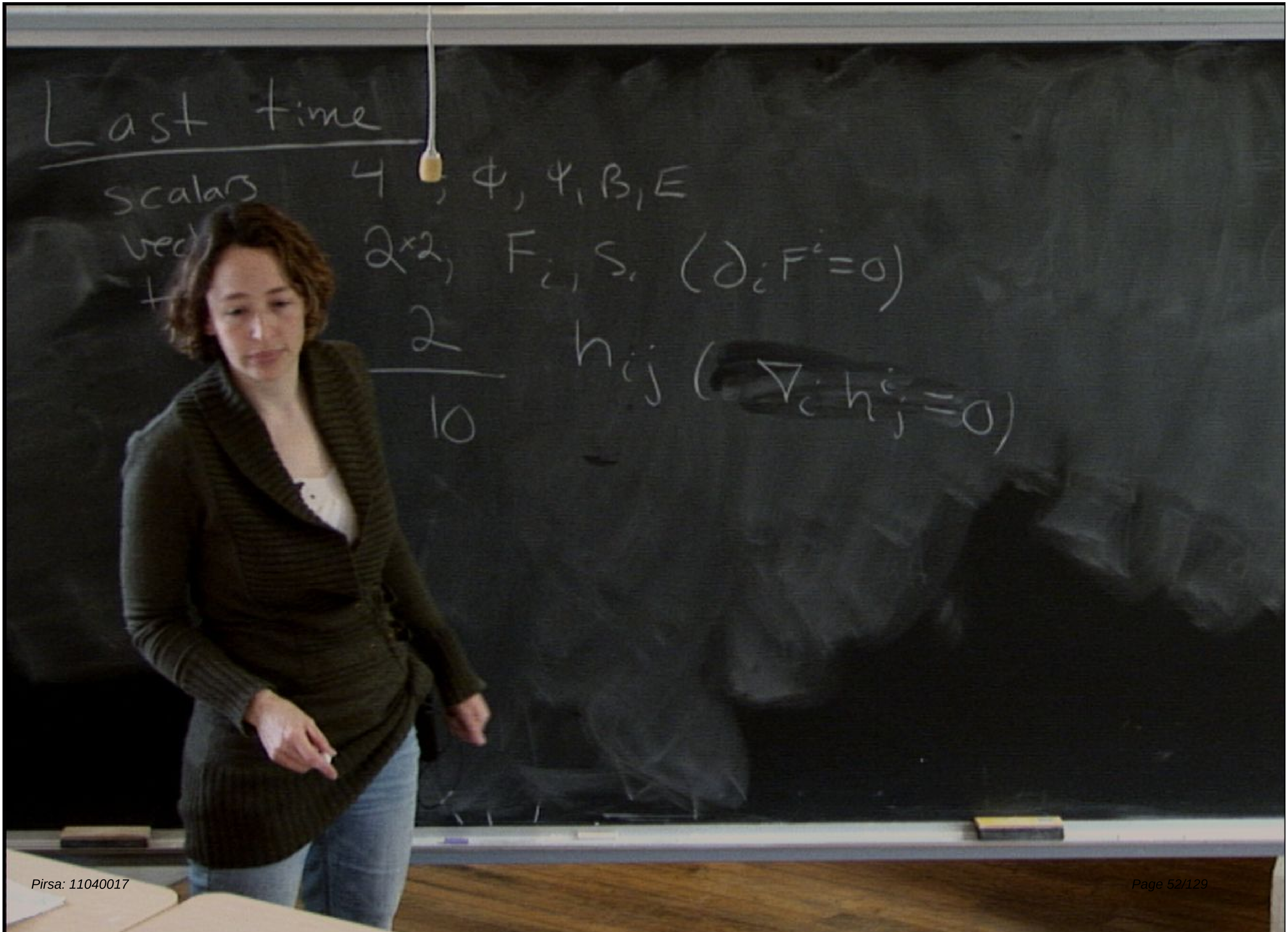

Last time
calars 4 ; Φ, Ψ, B, E
tors 2×2; F_i, S_i (∂_i F^i = 0)
sors

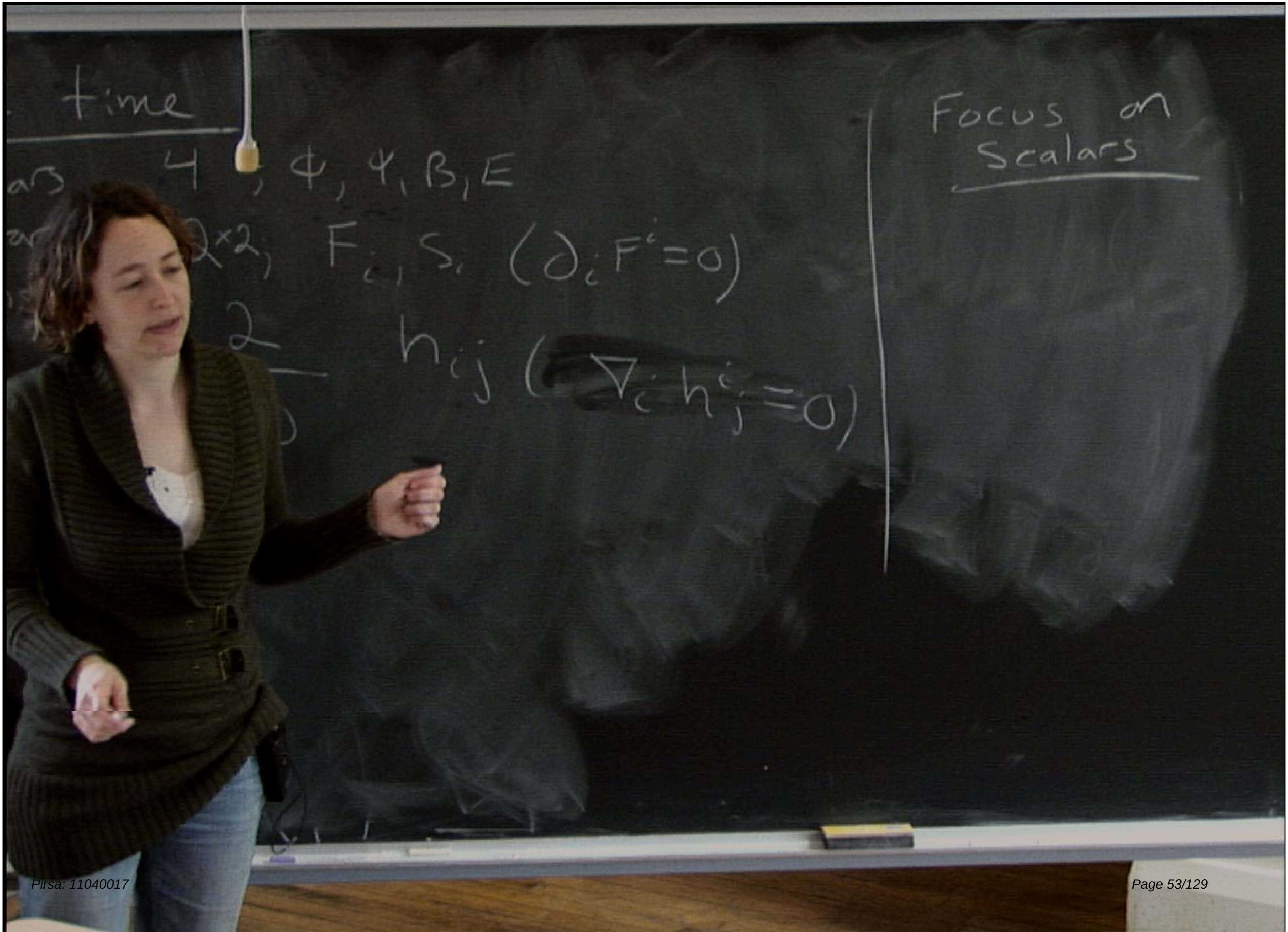

Last time
scalars 4, Φ, Ψ, B, E
vectors 2×2, F_i, S_i (∂_i F^i = 0)
tensors

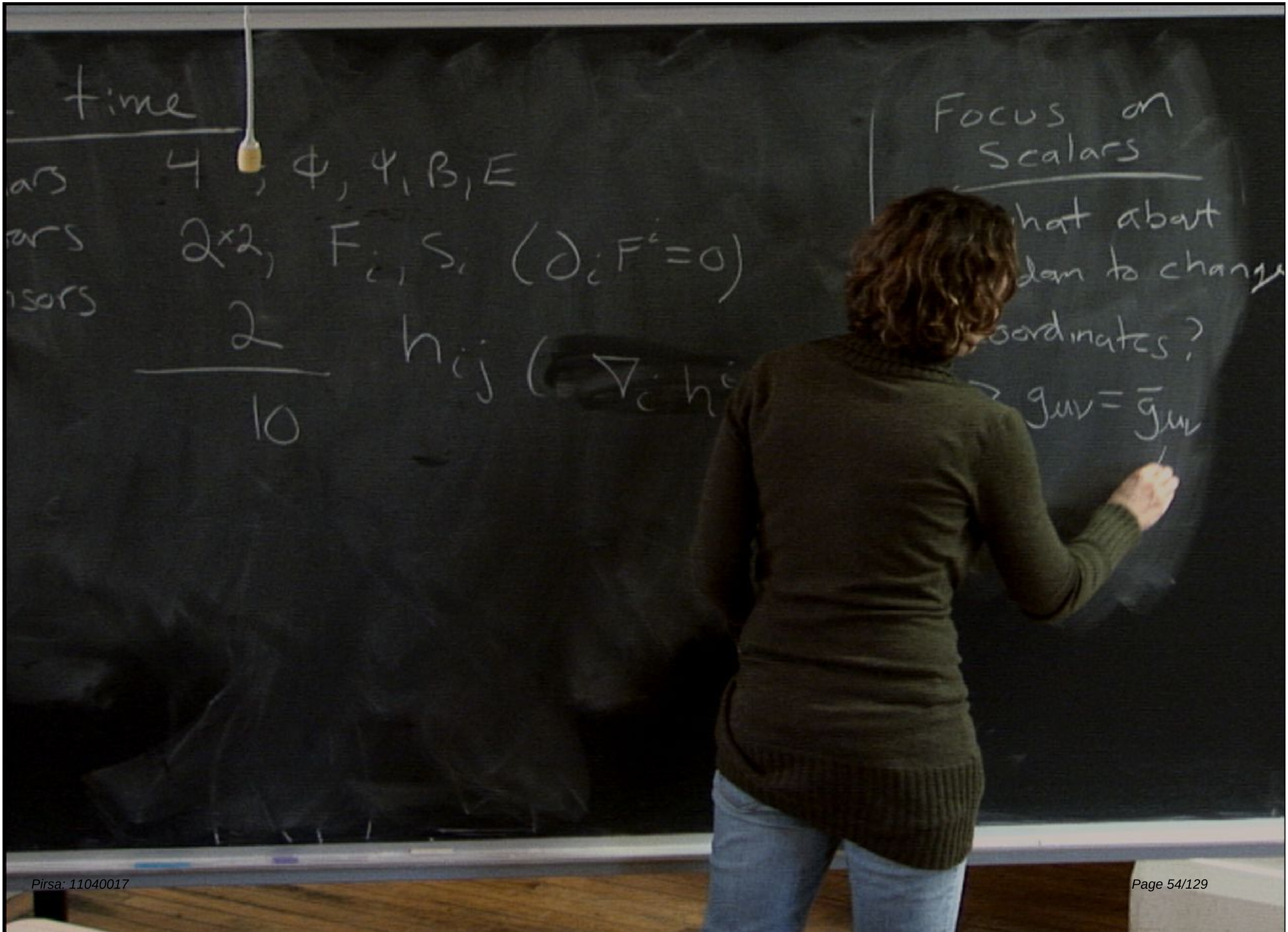

Last time
scalars 4, Φ, Ψ, B, E
vectors 2×2, F_i, S_i $(\partial_i F^i = 0)$
tensors h_{ij}

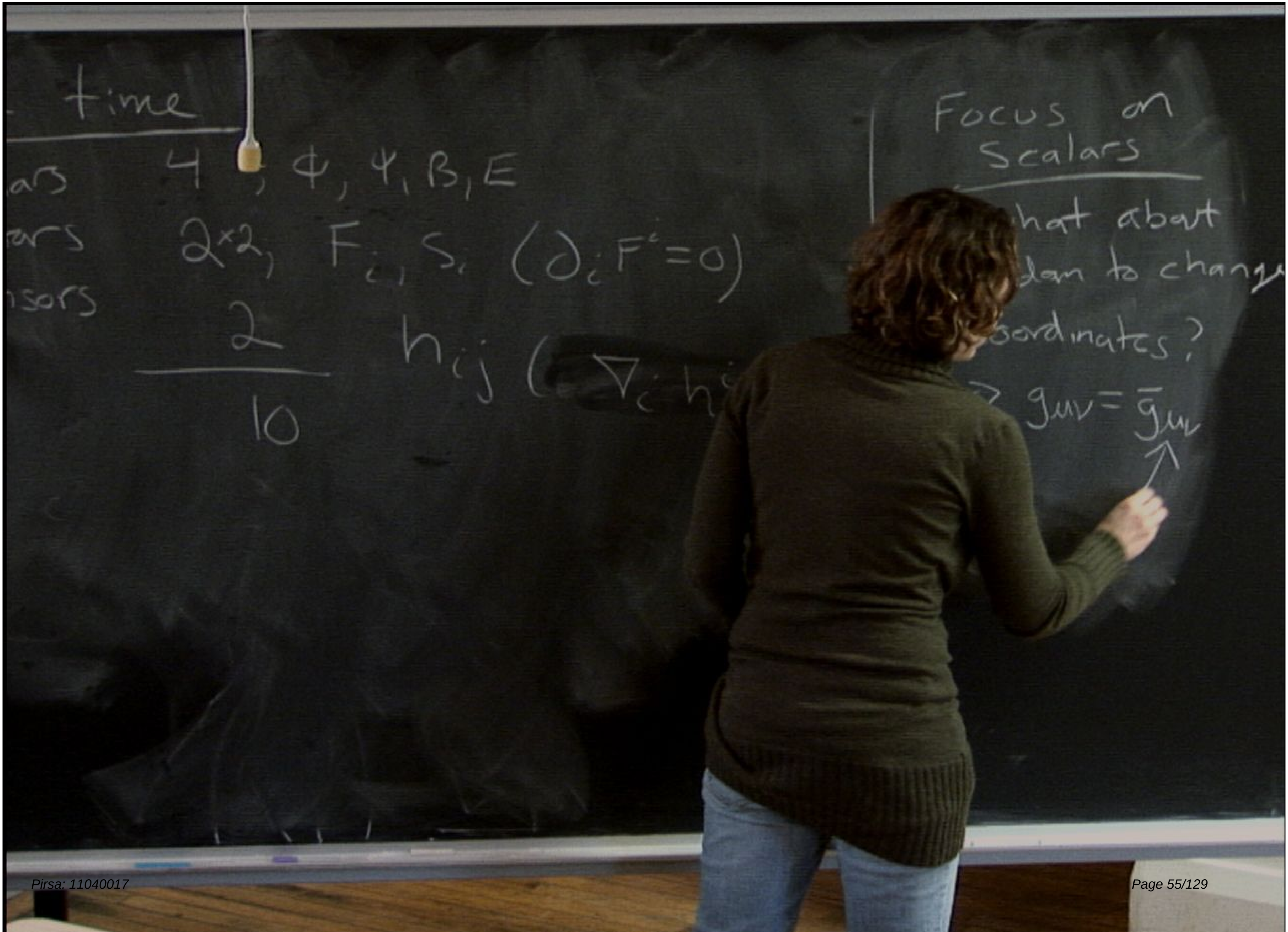

Last time
scalars 4, ϕ, ψ, B, E
vectors 2×2, F_i, S_i $(\partial_i F^i = 0)$
tensors 2 h_{ij}
10

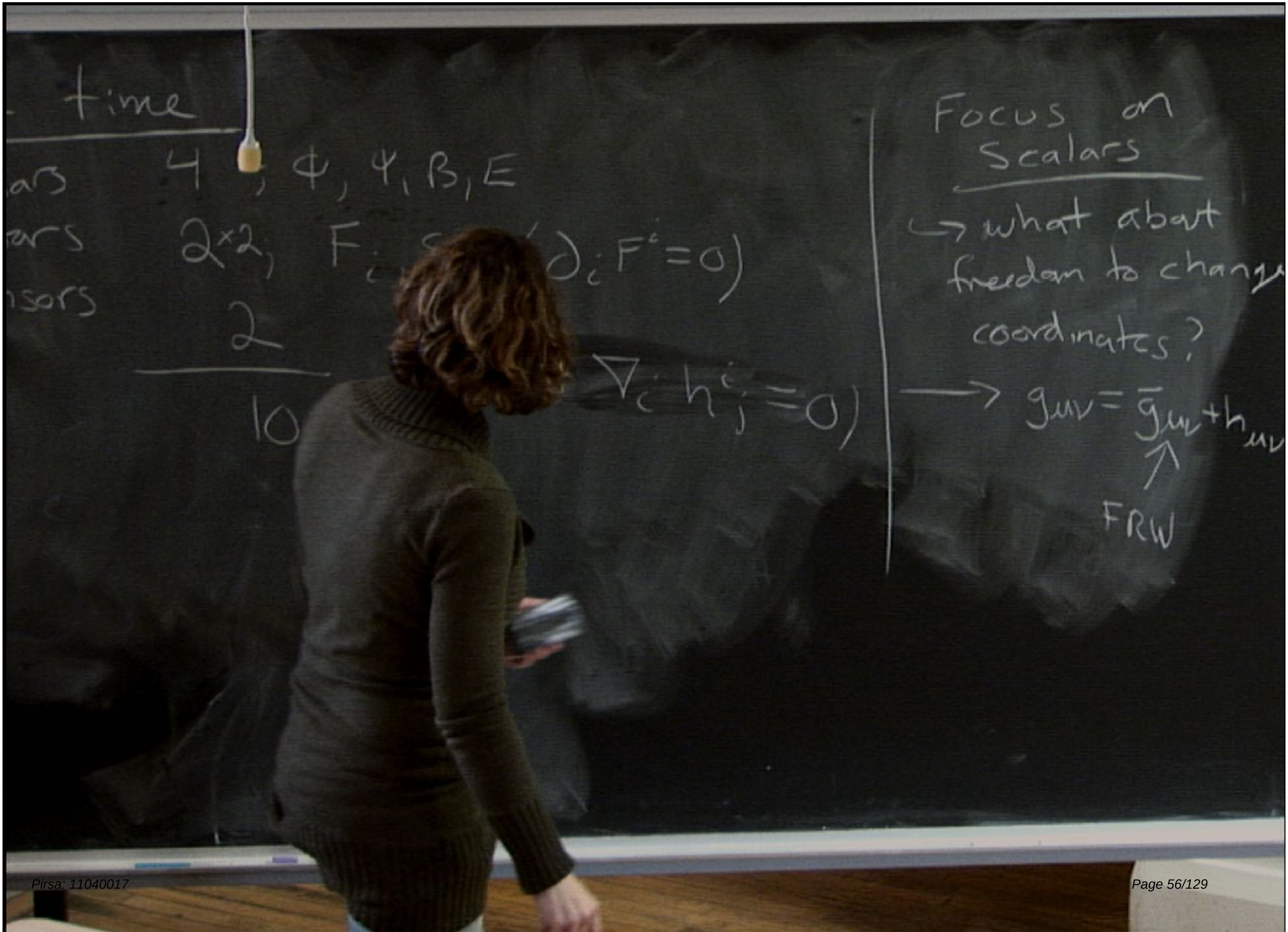

Last time
scalars 4, ϕ, ψ, B, E
vectors 2×2, F_i, S_i $(\partial_i F^i = 0)$
tensors 2 h_{ij} (traceless, tran.
10


Last time
scalars 4 ; Φ, Ψ, B, E
2×2, F_i, S_i $(\partial_i F^i = 0)$
2 h_{ij} $(\nabla_i h^i_j = 0)$
10


time
4 ; Φ, Ψ, B, E
2×2; F_i, S_i $(\partial_i F^i = 0)$
2 h_{ij} $(\nabla_i h^i_j = 0)$
Focus on Scalars


time
4 ; Φ, Ψ, B, E
2×2, F_i, S_i (∂_i F^i = 0)
2 h_ij (∇_i h^i
10
Focus on Scalars
what about
freedom to change
coordinates?
g_μν = ḡ_μν


time
ars 4 Φ, Ψ, B, E
ars 2×2, F_i, S_i $(\partial_i F^i = 0)$
nsors 2 h_{ij} $(\nabla_i h$
10
Focus on Scalars
hat about
dom to change
ordinates?
$g_{\mu\nu} = \bar{g}_{\mu\nu}$


time
4 , Φ, Ψ, B, E
2×2,
2
10
Focus on Scalars
what about freedom to change coordinates?
FRW

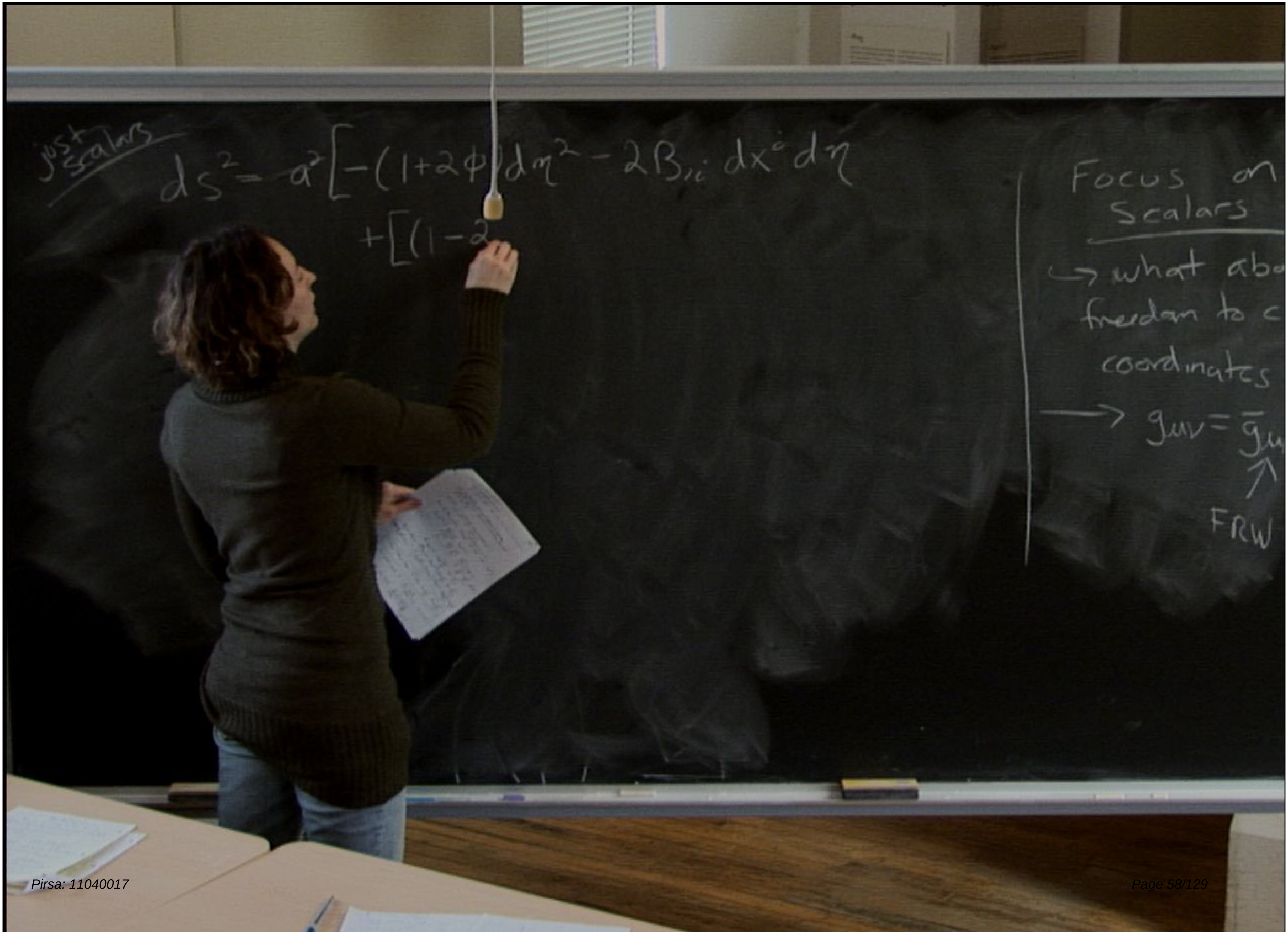
Focus on Scalars

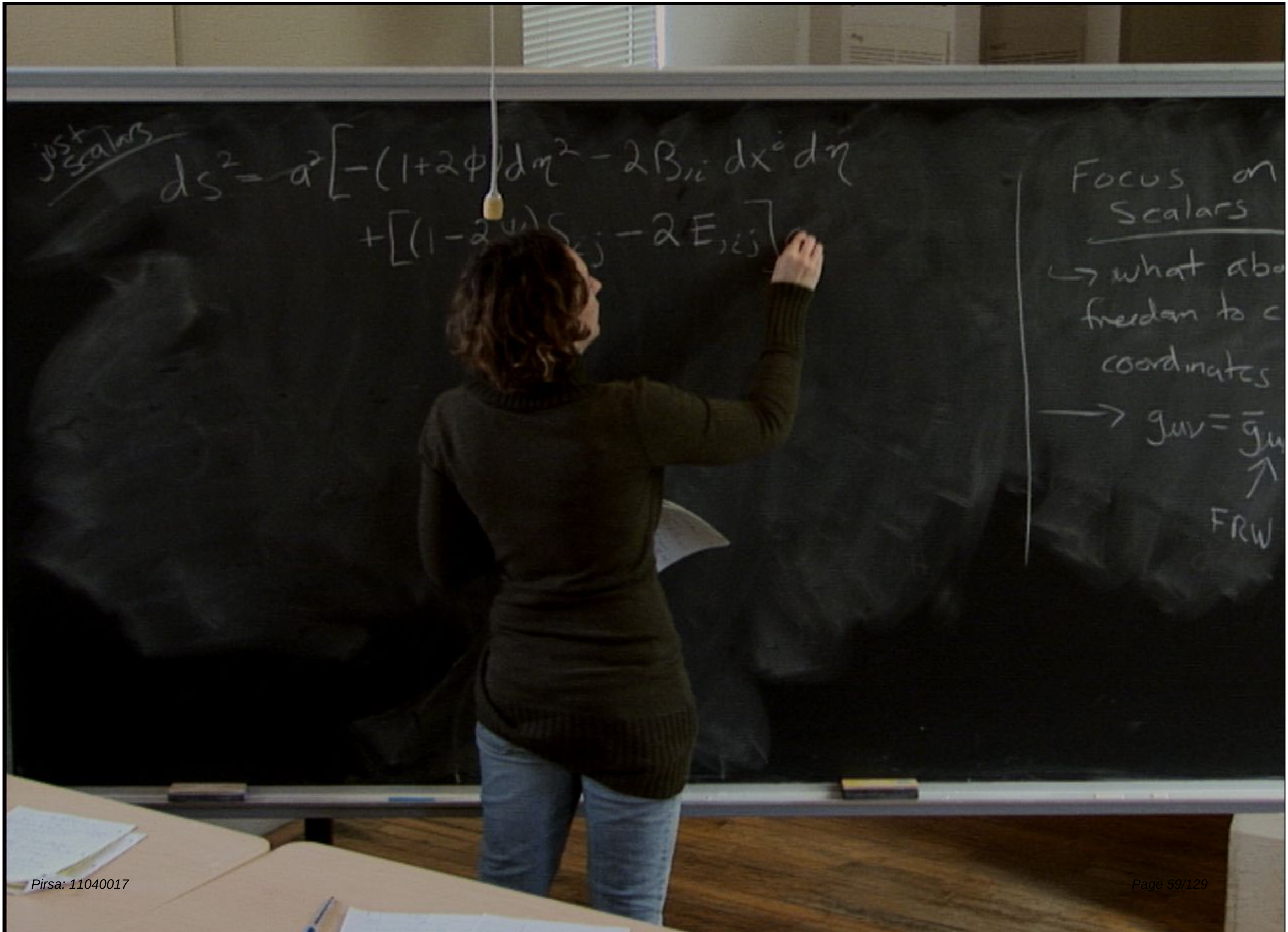
→ what about freedom to change coordinates?

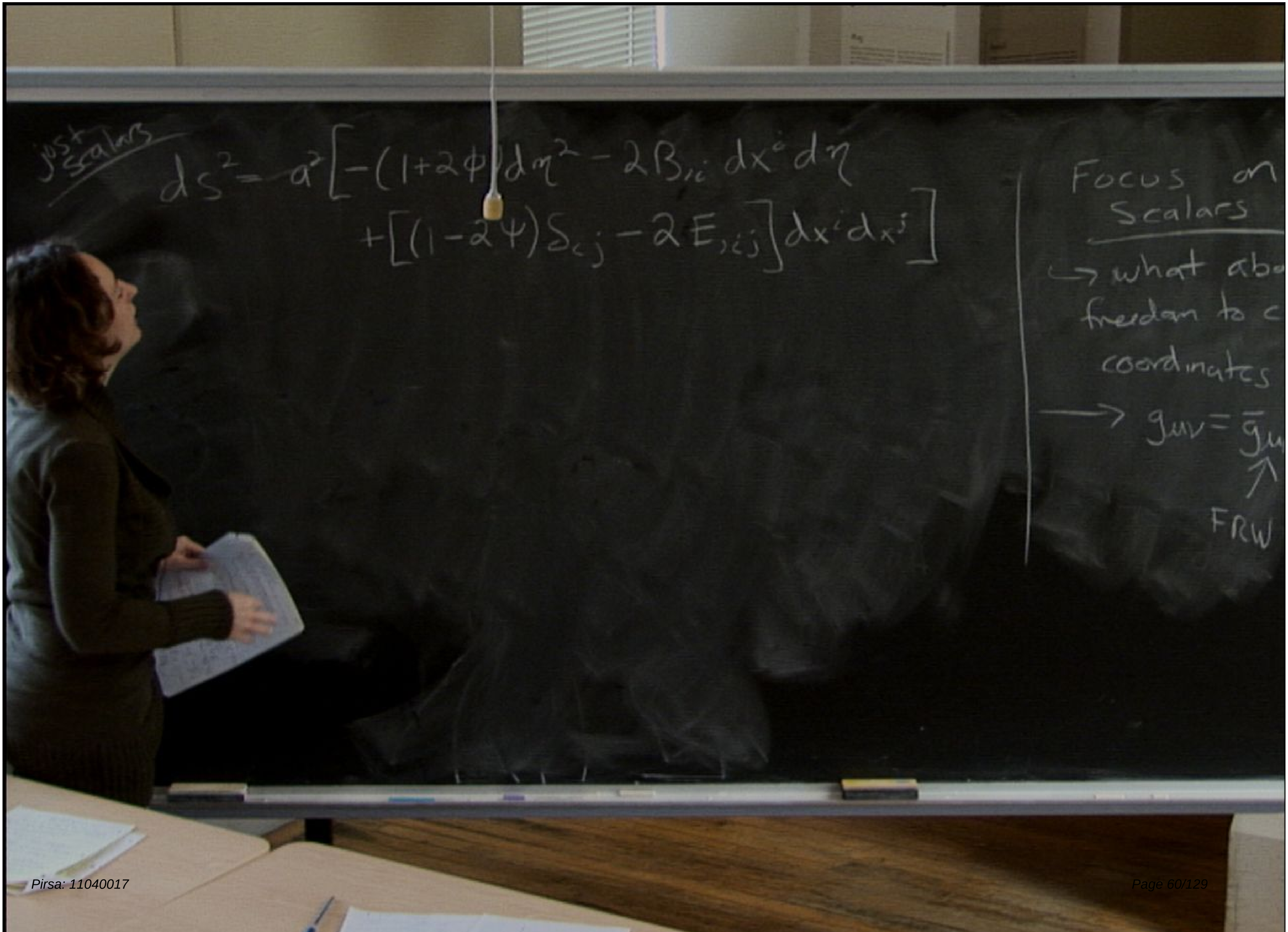
→ $g_{\mu\nu} = \bar{g}_{\mu\nu} + h_{\mu\nu}$

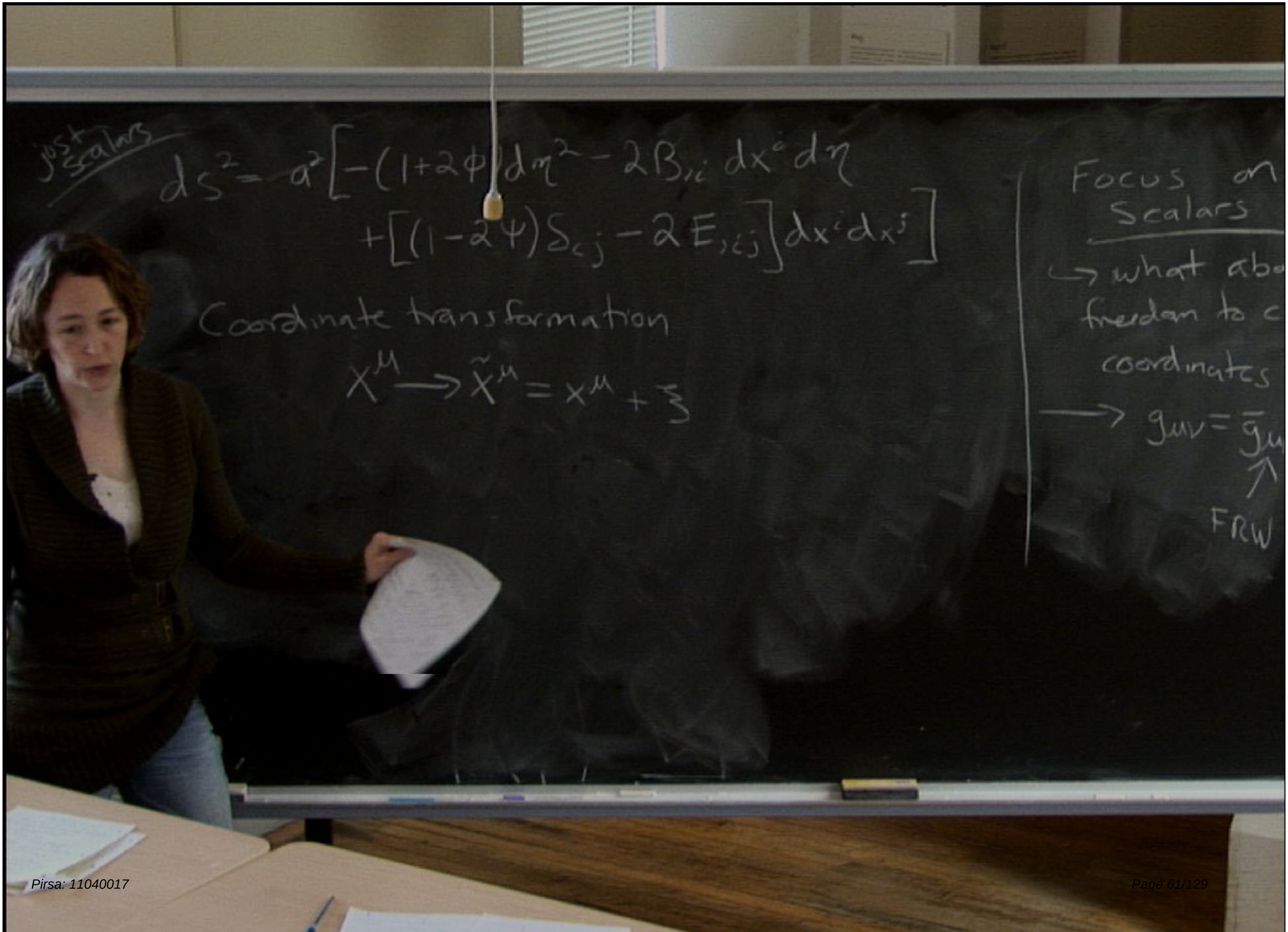
$\uparrow$

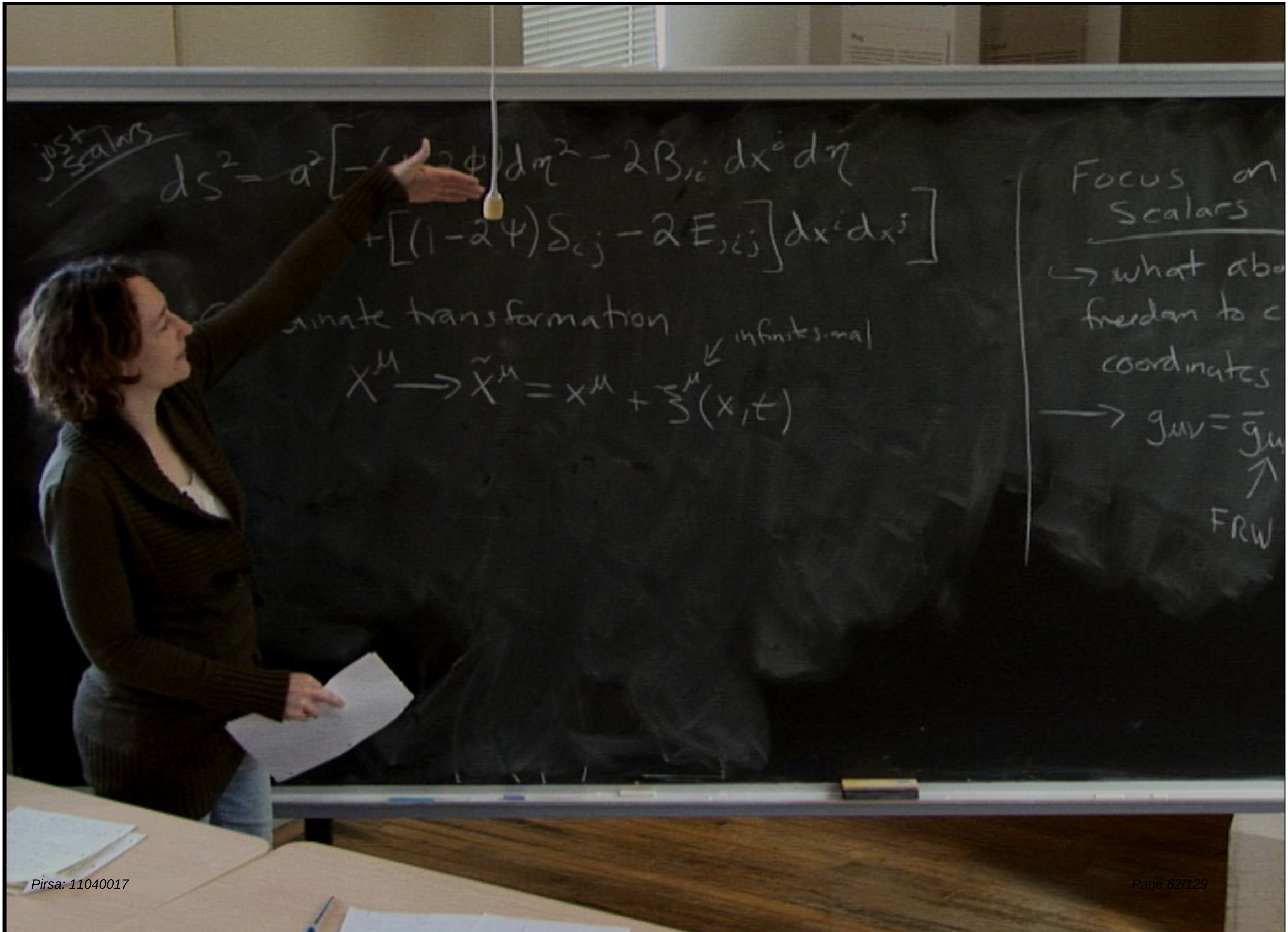
FRW


just scalars
ds² = a²[-(1+2φ)dη² - 2B,ᵢ dxⁱ dη
+[(1-2
Focus on
Scalars
what abo
freedom to c
coordinates
gμν = ḡμ
FRW

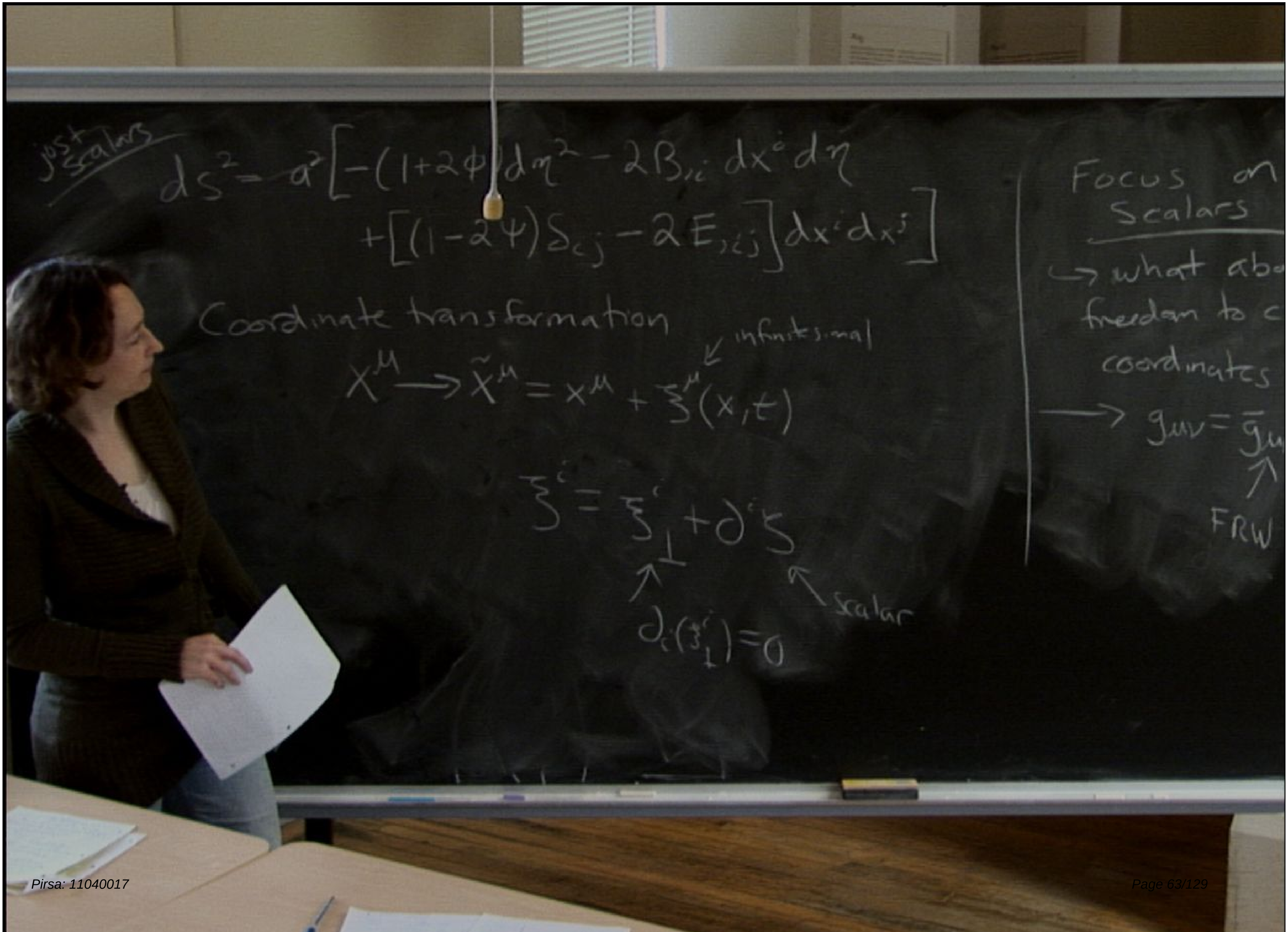

just scalars
$ds^2 = a^2\left[-(1+2\phi)d\eta^2 - 2B_{,i}\, dx^i d\eta\right.$
Focus on Scalars
what
freedom to
coordinates
$g_{\mu\nu} = \bar{g}$
FRW


just scalars
$ds^2 = a^2[-(1+2\phi)d\eta^2 - 2B_{,i}\, dx^i d\eta$
$+[(1-2\psi)\delta_{ij} - 2E_{,ij}]dx^i dx^j]$
Focus on
Scalars
what abo
freedom to c
coordinates
$g_{\mu\nu} = \bar{g}_{\mu}$
FRW

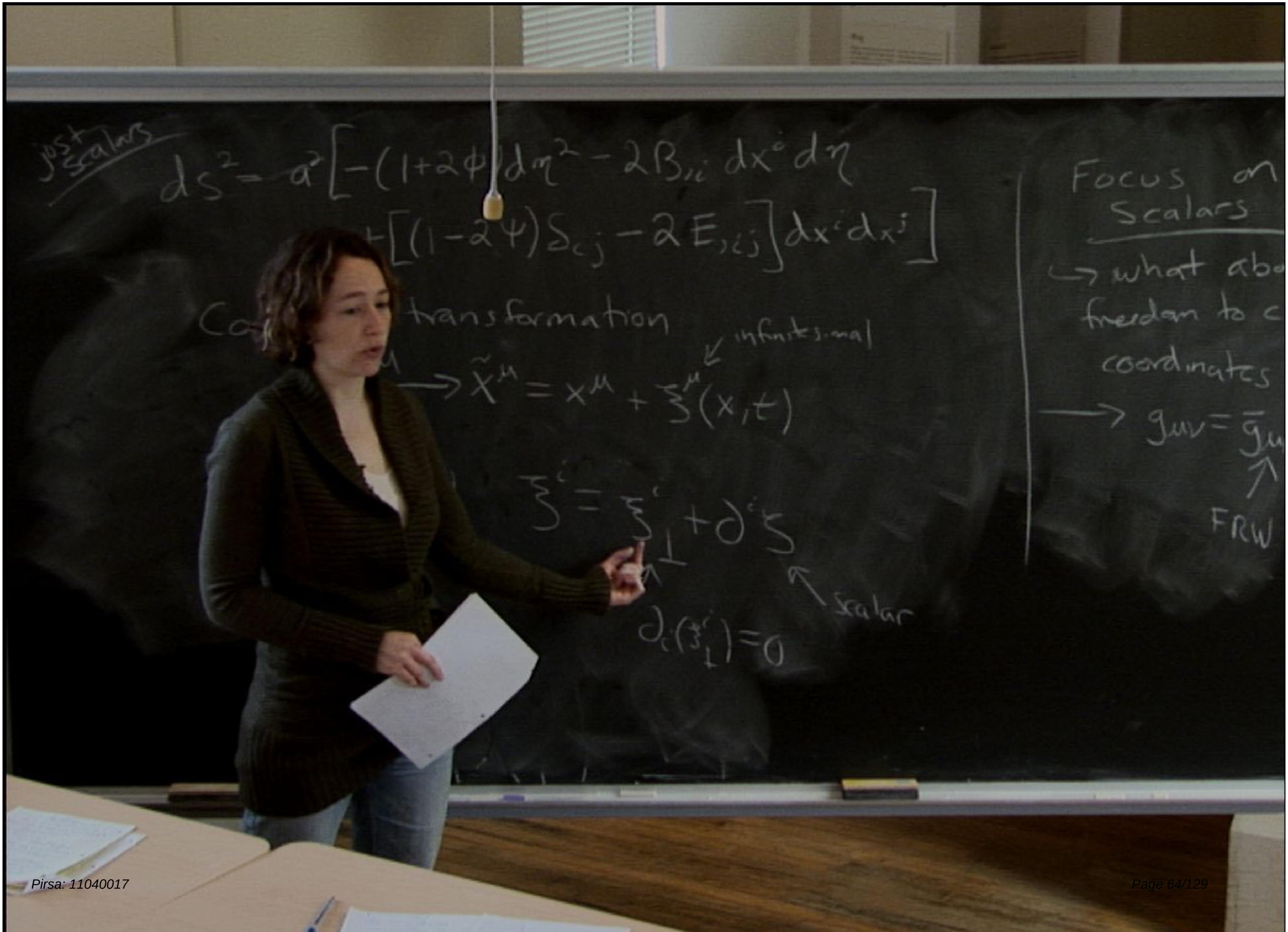

just scalars
$ds^2 = a^2\left[-(1+2\phi)d\eta^2 - 2B_{,i}\,dx^i d\eta + \left[(1-2\psi)\delta_{ij} - 2E_{,ij}\right]dx^i dx^j\right]$
Coordinate transformation
$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi$
Focus on Scalars
what abo
freedom to c
coordinates
$g_{\mu\nu} = \bar{g}_{\mu}$
FRW

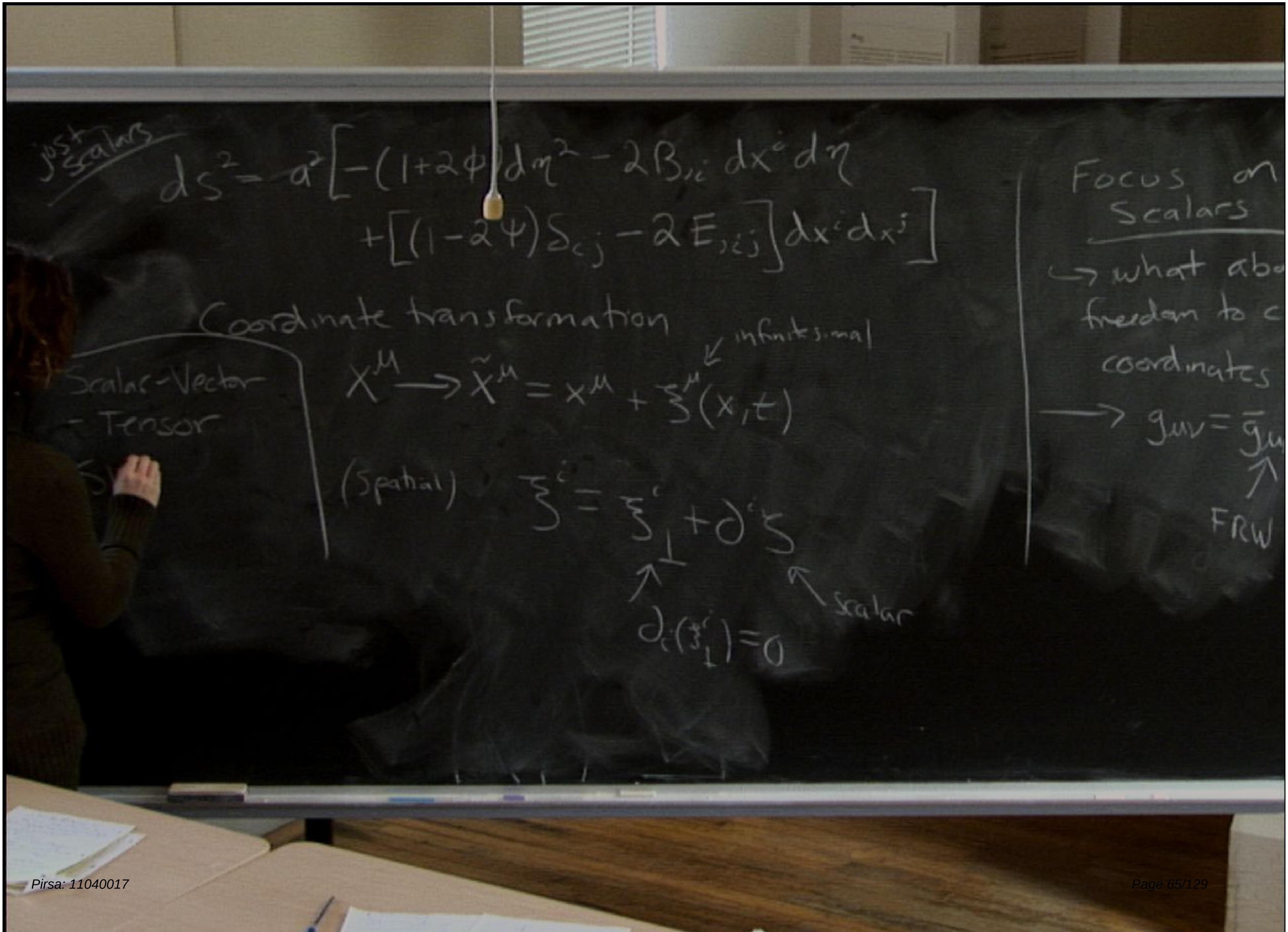


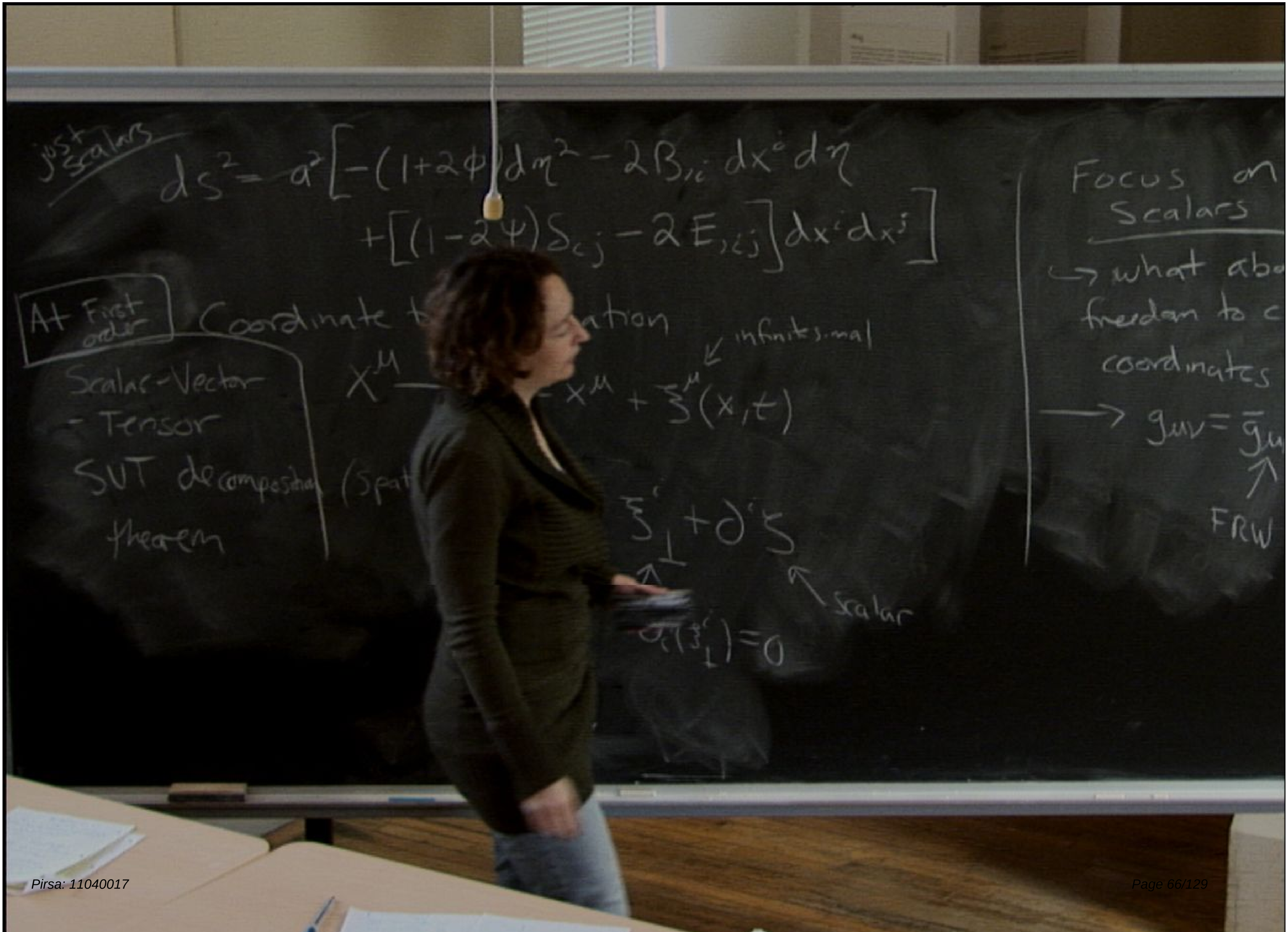
just scalars
$ds^2 = a^2\left[-(1+2\Phi)d\eta^2 - 2B_{,i}\,dx^i d\eta\right.$
$\left.+\left[(1-2\Psi)\delta_{ij} - 2E_{,ij}\right]dx^i dx^j\right]$
transformation
infinitesimal
$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$
Focus on Scalars
what abo
freedom to c
coordinates
$g_{\mu\nu} = \bar{g}_{\mu}$
FRW

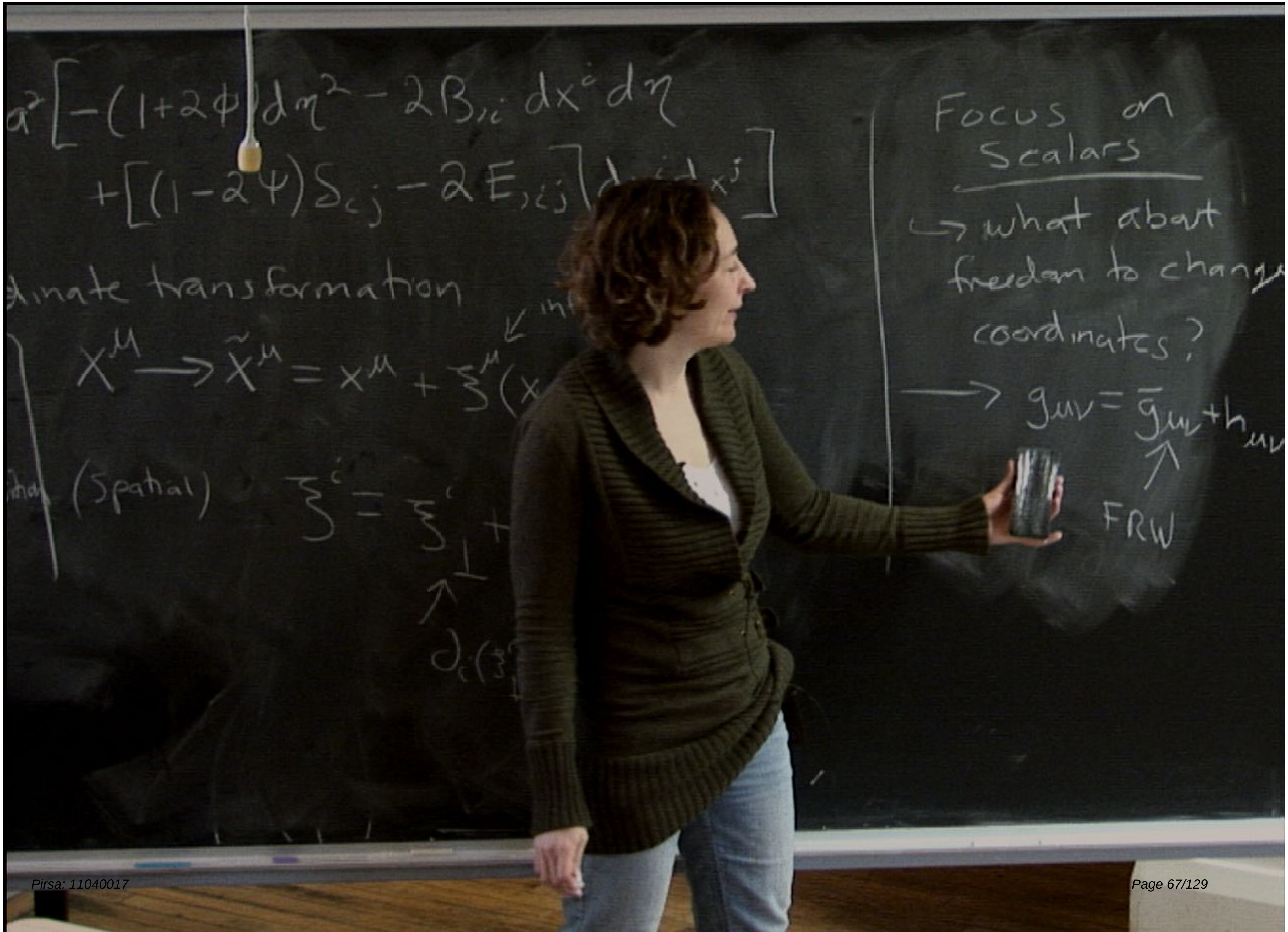


just scalars
$ds^2 = a^2\left[-(1+2\phi)d\eta^2 - 2B_{,i}\,dx^i d\eta + \left[(1-2\psi)\delta_{ij} - 2E_{,ij}\right]dx^i dx^j\right]$
Coordinate transformation
infinitesimal
$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$
$\xi^i = \xi^i_\perp + \partial^i \xi$
$\partial_i(\xi^i_\perp) = 0$
scalar
Focus on Scalars
what abo
freedom to c
coordinates
$g_{\mu\nu} = \bar{g}_{\mu}$
FRW


just scalars
ds² = a²[−(1+2φ)dη² − 2B,i dx^i dη
+[(1−2ψ)δij − 2E,ij]dx^i dx^j]
transformation
infinitesimal
x̃^μ = x^μ + ξ^μ(x,t)
ξ^i = ξ^i⊥ + ∂^i ξ
scalar
∂i(ξ^i⊥) = 0
Focus on
Scalars
coordinates
FRW


just scalars
$ds^2 = a^2\left[-(1+2\phi)d\eta^2 - 2B_{,i}\, dx^i d\eta + \left[(1-2\psi)\delta_{ij} - 2E_{,ij}\right]dx^i dx^j\right]$
Coordinate transformation
infinitesimal
$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$
Scalar-Vector-Tensor
(spatial)
$\xi^i = \xi^i_\perp + \partial^i \xi$
scalar
$\partial_i(\xi^i_\perp) = 0$
Focus on Scalars
what abo
freedom to c
coordinates
$g_{\mu\nu} = \bar{g}_{\mu}$
FRW


just scalars
ds² = a²[−(1+2Φ)dη² − 2B,i dx^i dη
+[(1−2Ψ)δij − 2E,ij] dx^i dx^j]
At First order
Coordinate
ation
infinitesimal
Scalar-Vector
-Tensor
SVT decomposition (Spat
theorem
x^μ
x^μ + ξ^μ(x,t)
ξ^i⊥ + ∂^i ξ
Scalar
∂i(ξ^i⊥) = 0
Focus on
Scalars
what abo
freedom to c
coordinates
gμν =
FRW


Focus on Scalars
what about freedom to change coordinates?
$g_{\mu\nu} = \bar{g}_{\mu\nu} + h_{\mu\nu}$
FRW
transformation
$x^\mu \rightarrow \tilde{x}^\mu = x^\mu + \xi^\mu$
(spatial)
$\xi^i = \xi^i_\perp$

$1+2\phi)d\eta^2 - 2B_{,i}\, dx^i d\eta$

$(1-2\psi)\delta_{ij} - 2E_{,ij}\big]dx^i dx^j\big]$

transformation

infinitesimal

$\longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$

atial) $\xi^i = \xi^i_\perp + \partial^i \zeta$

scalar

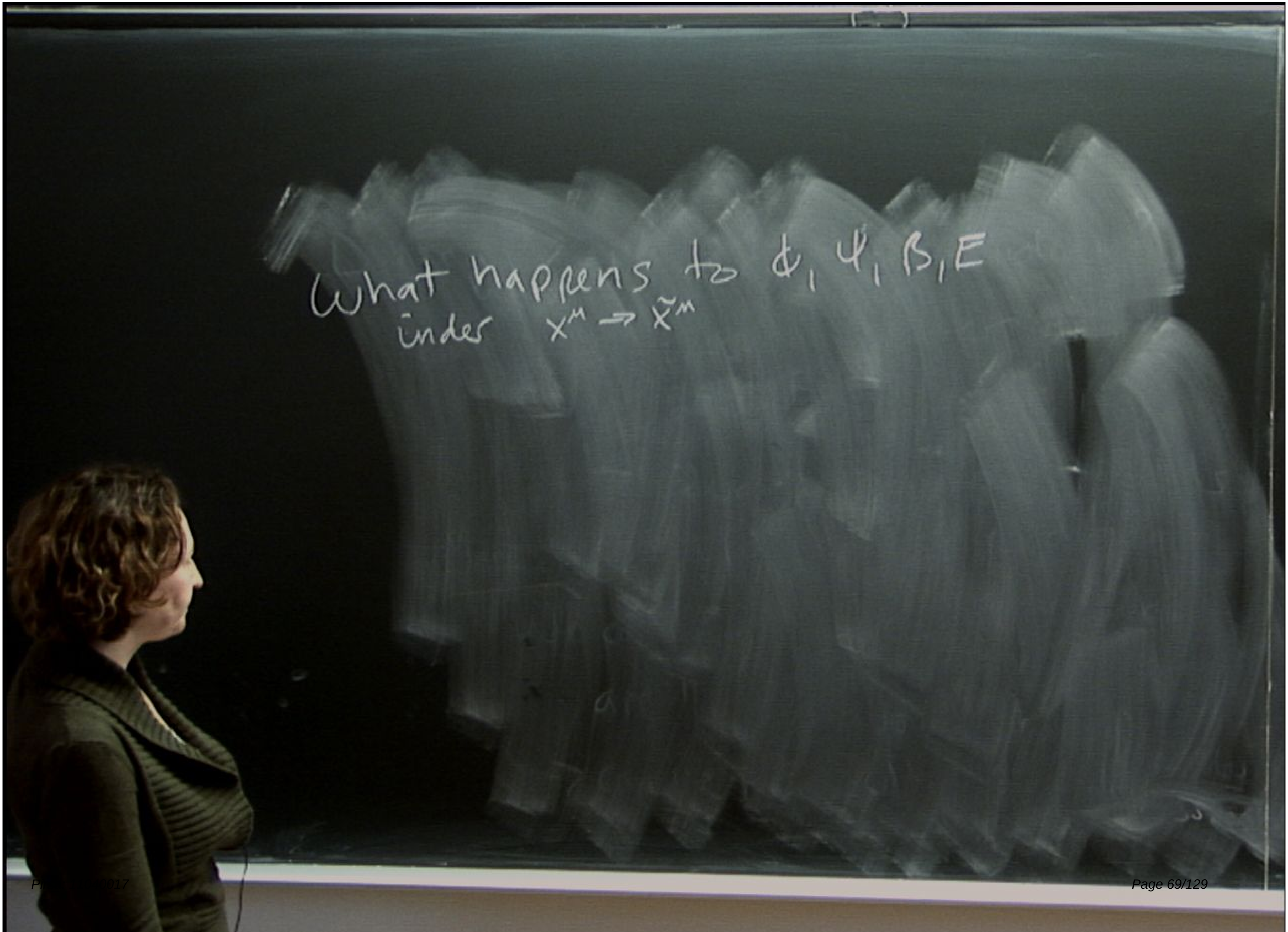
$\partial_i(\xi^i_\perp) = 0$

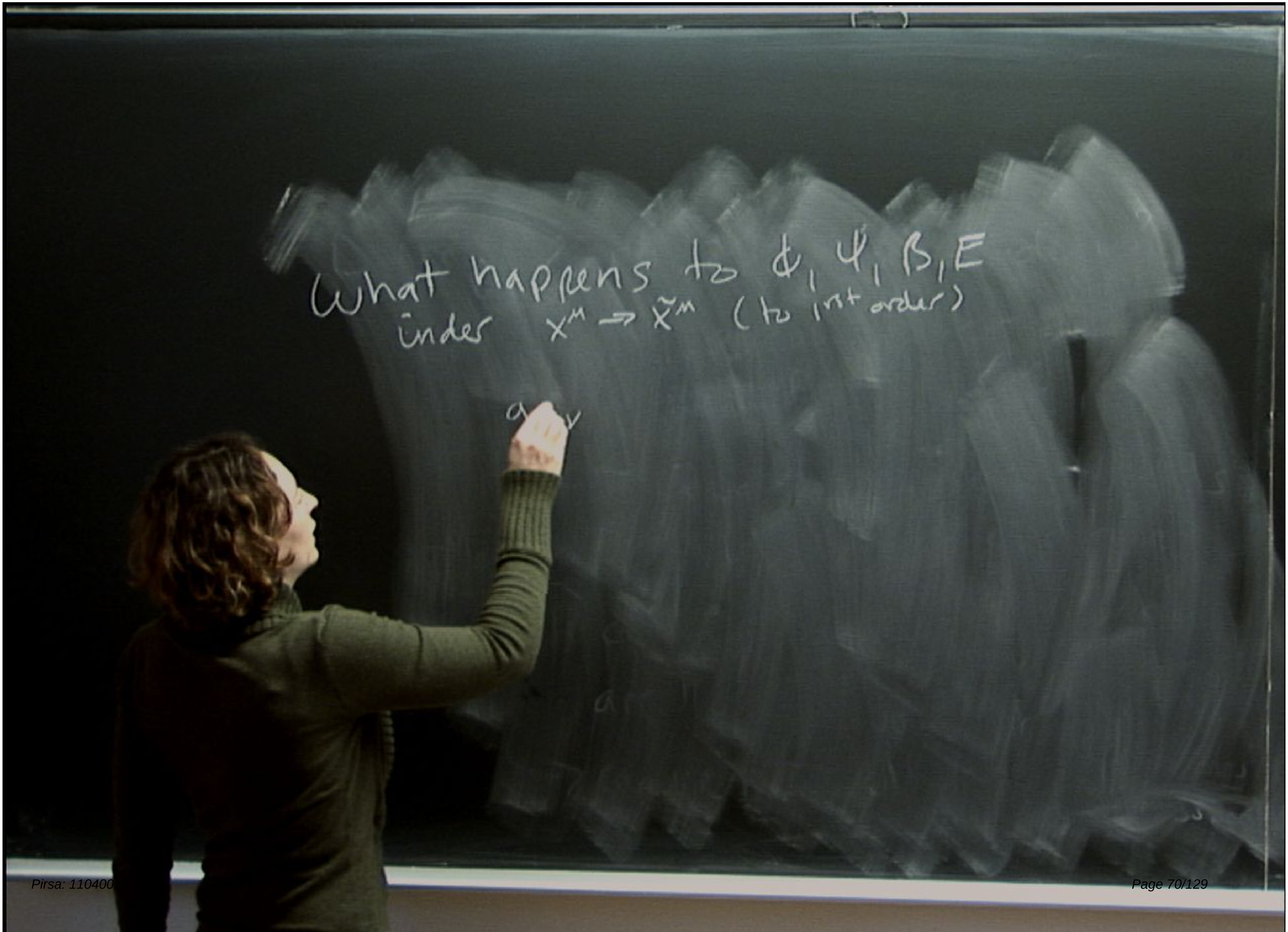
Focus on Scalars

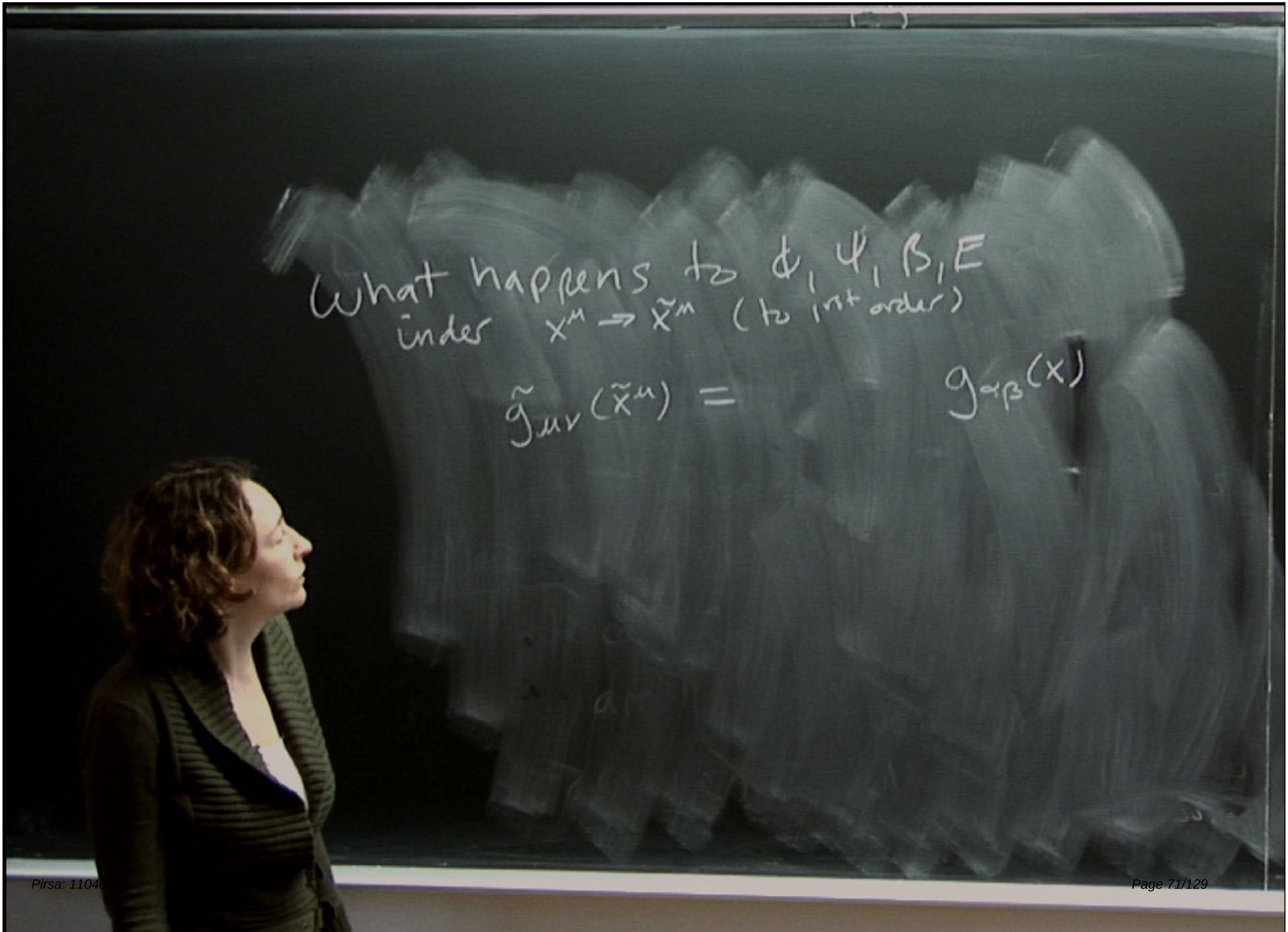
↳ what about freedom to change coordinates?

$\longrightarrow g_{\mu\nu} = \bar{g}_{\mu\nu} + h_{\mu\nu}$

FRW

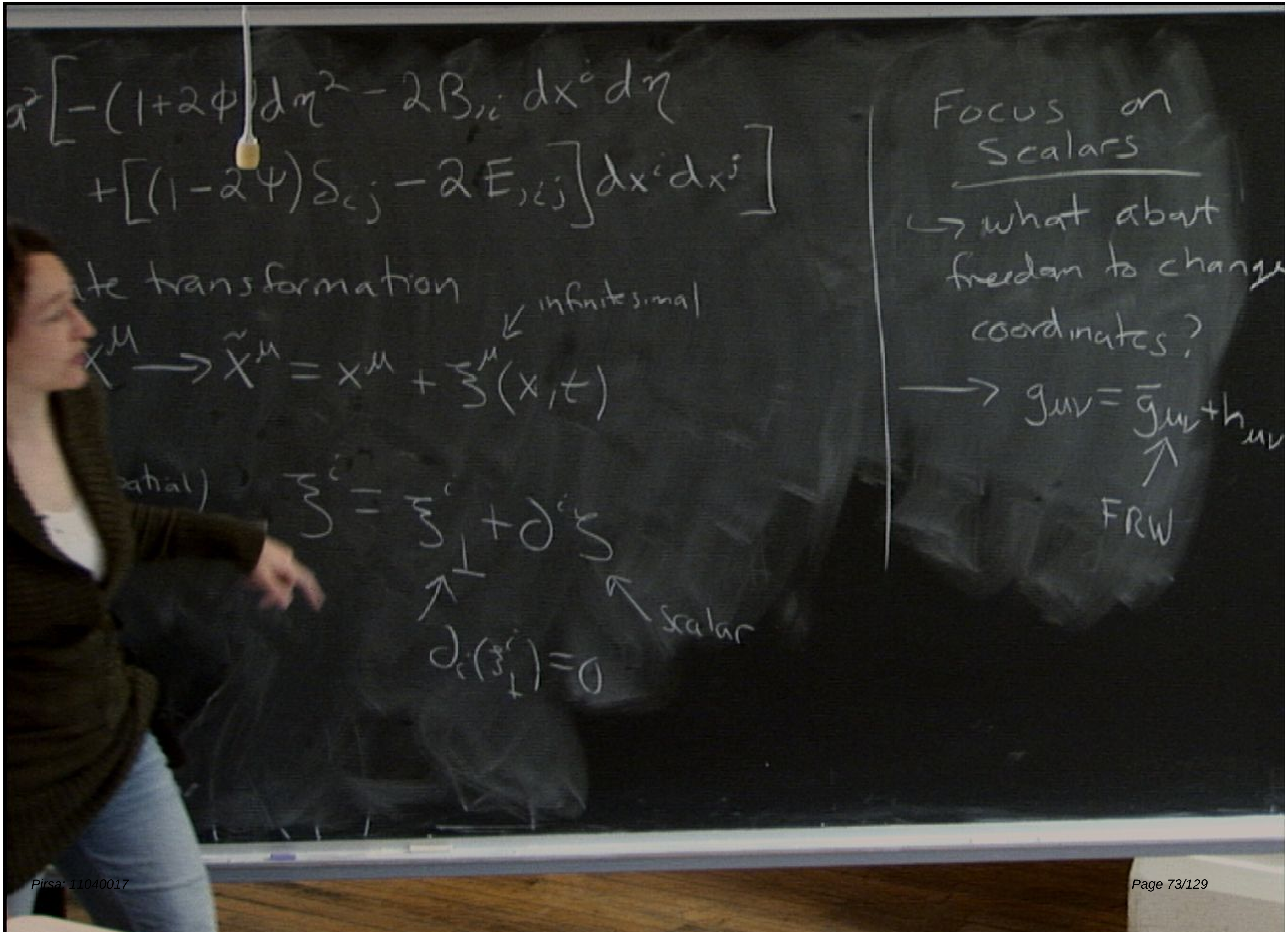

What happens to ϕ, ψ, B, E
under $x^\mu \to \tilde{x}^\mu$

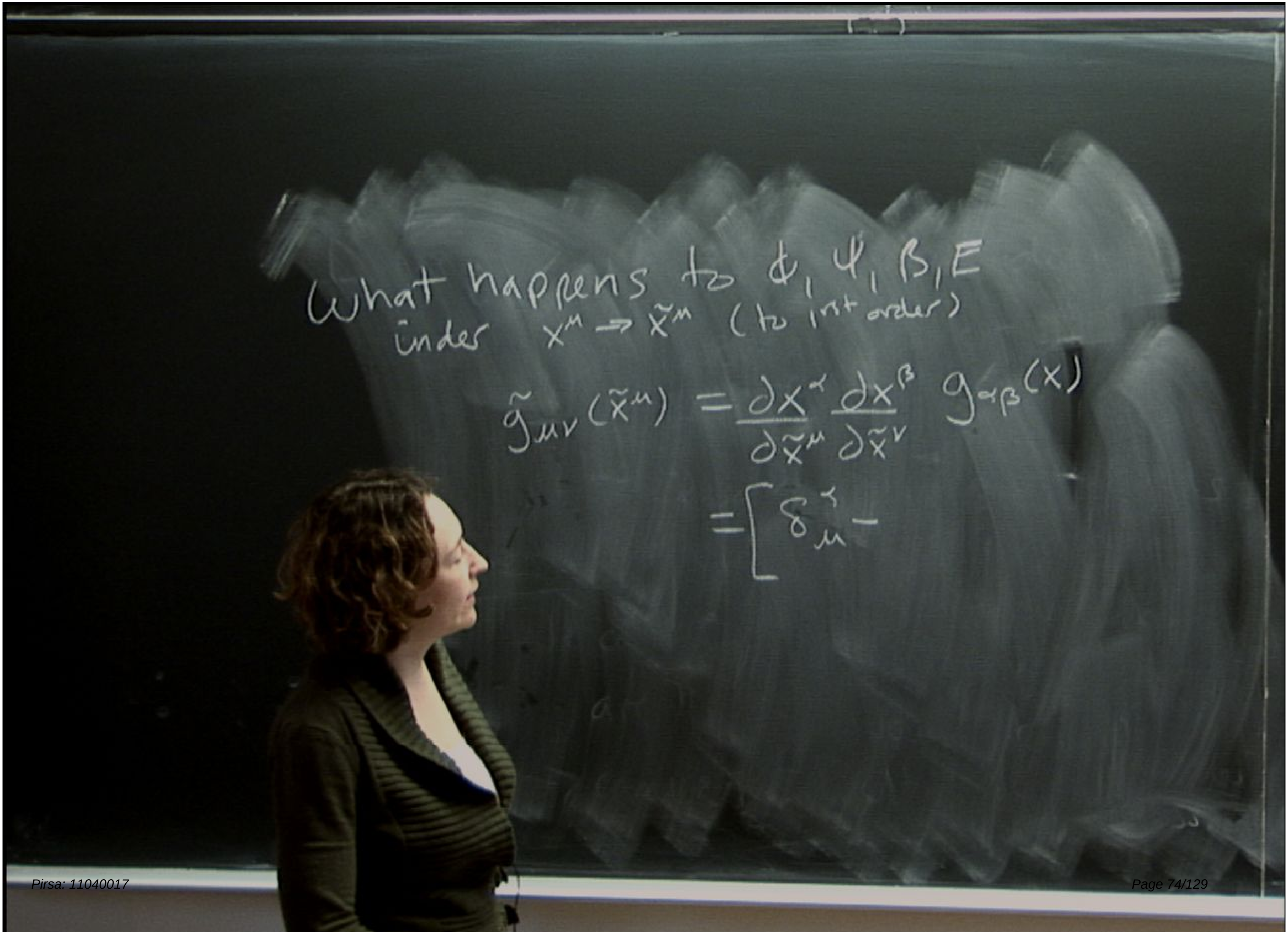

What happens to Φ, Ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)

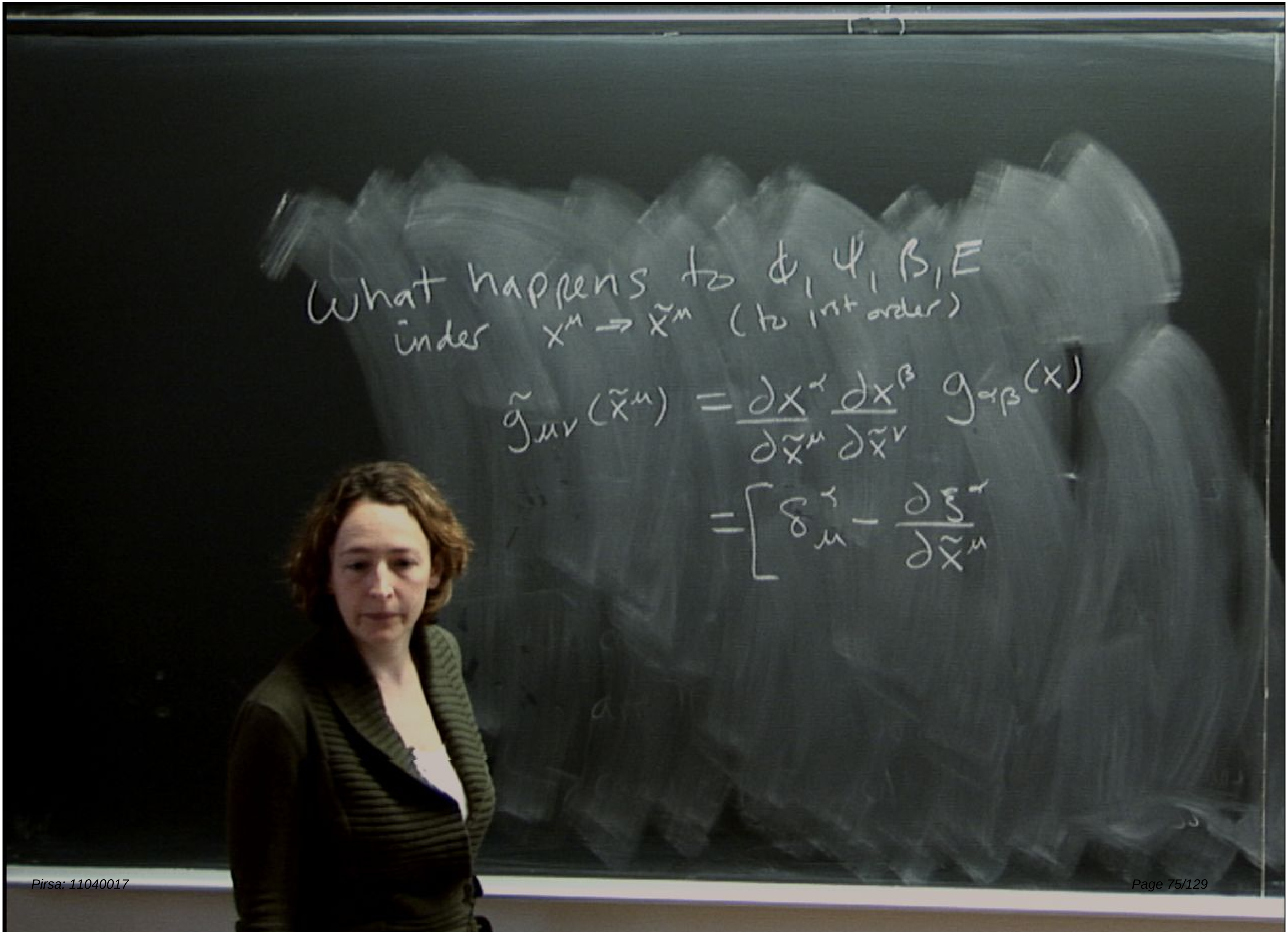

What happens to Φ, Ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)
$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \quad g_{\alpha\beta}(x)$

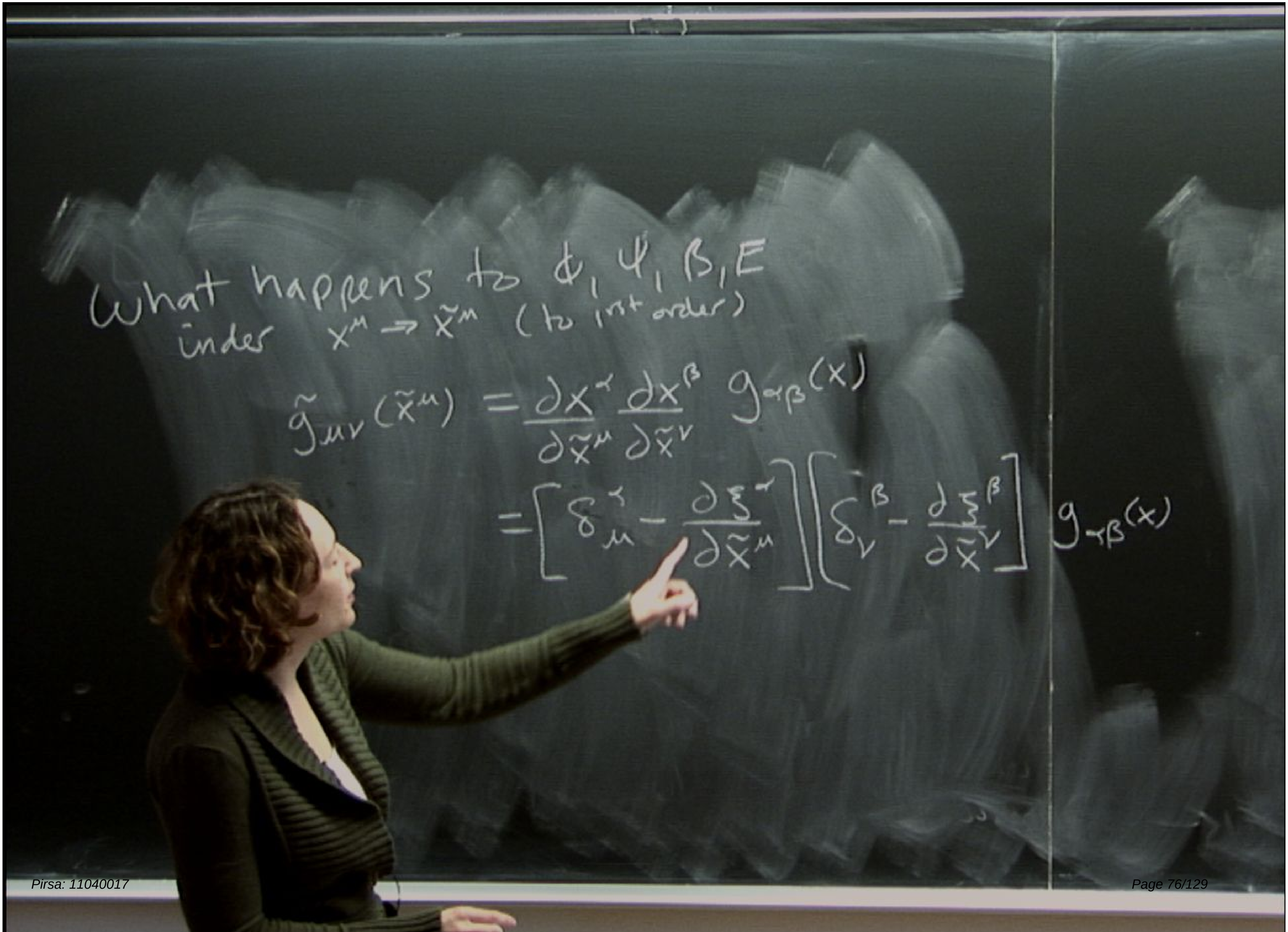
What happens to ϕ, ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)

$$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu} \frac{\partial x^\beta}{\partial \tilde{x}^\nu} g_{\alpha\beta}(x)$$


$a^2\Big[-(1+2\phi)d\eta^2 - 2B_{,i}\,dx^i d\eta$
$+\big[(1-2\psi)\delta_{ij} - 2E_{,ij}\big]dx^i dx^j\Big]$
ate transformation
infinitesimal
$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$
patial)
$\xi^i = \xi^i_\perp + \partial^i \xi$
scalar
$\partial_i(\xi^i_\perp) = 0$
Focus on Scalars
what about freedom to change coordinates?
$g_{\mu\nu} = \bar{g}_{\mu\nu} + h_{\mu\nu}$
FRW


What happens to Φ, Ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)
$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu} \frac{\partial x^\beta}{\partial \tilde{x}^\nu} g_{\alpha\beta}(x)$
$= [\delta^\alpha_\mu -$


What happens to ϕ, ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)
$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu} \frac{\partial x^\beta}{\partial \tilde{x}^\nu} g_{\alpha\beta}(x)$
$= \Big[\delta^\alpha_\mu - \frac{\partial \xi^\alpha}{\partial \tilde{x}^\mu}$


What happens to Φ, Ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)
$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu}\frac{\partial x^\beta}{\partial \tilde{x}^\nu} g_{\alpha\beta}(x)$
$= \left[\delta^\alpha_\mu - \frac{\partial \xi^\alpha}{\partial \tilde{x}^\mu}\right]\left[\delta_\nu^\beta - \frac{\partial \xi^\beta}{\partial \tilde{x}^\nu}\right] g_{\alpha\beta}(x)$

What happens to Φ, Ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)

$$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu}\frac{\partial x^\beta}{\partial \tilde{x}^\nu}\, g_{\alpha\beta}(x)$$

$$= \left[\delta^\alpha_\mu - \frac{\partial \xi^\alpha}{\partial \tilde{x}^\mu}\right]\left[\delta^\beta_\nu - \frac{\partial \xi^\beta}{\partial \tilde{x}^\nu}\right] g_{\alpha\beta}(x)$$

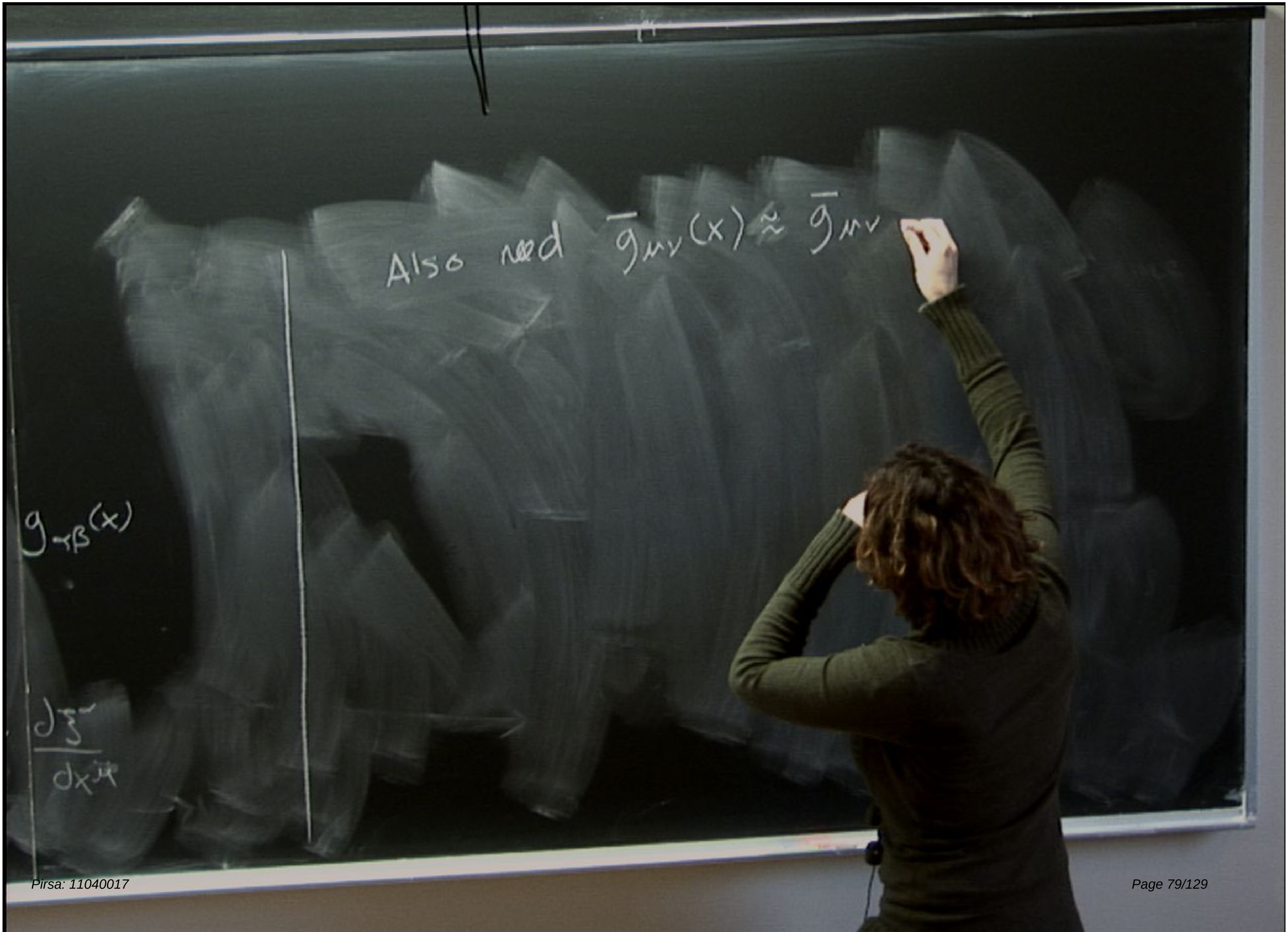
$$\approx g_{\mu\nu}(x) - g_{\mu\beta}\frac{\partial \xi^\beta}{\partial x^\nu} - g_{\alpha\nu}\frac{\partial \xi^\alpha}{\partial x^\mu}$$

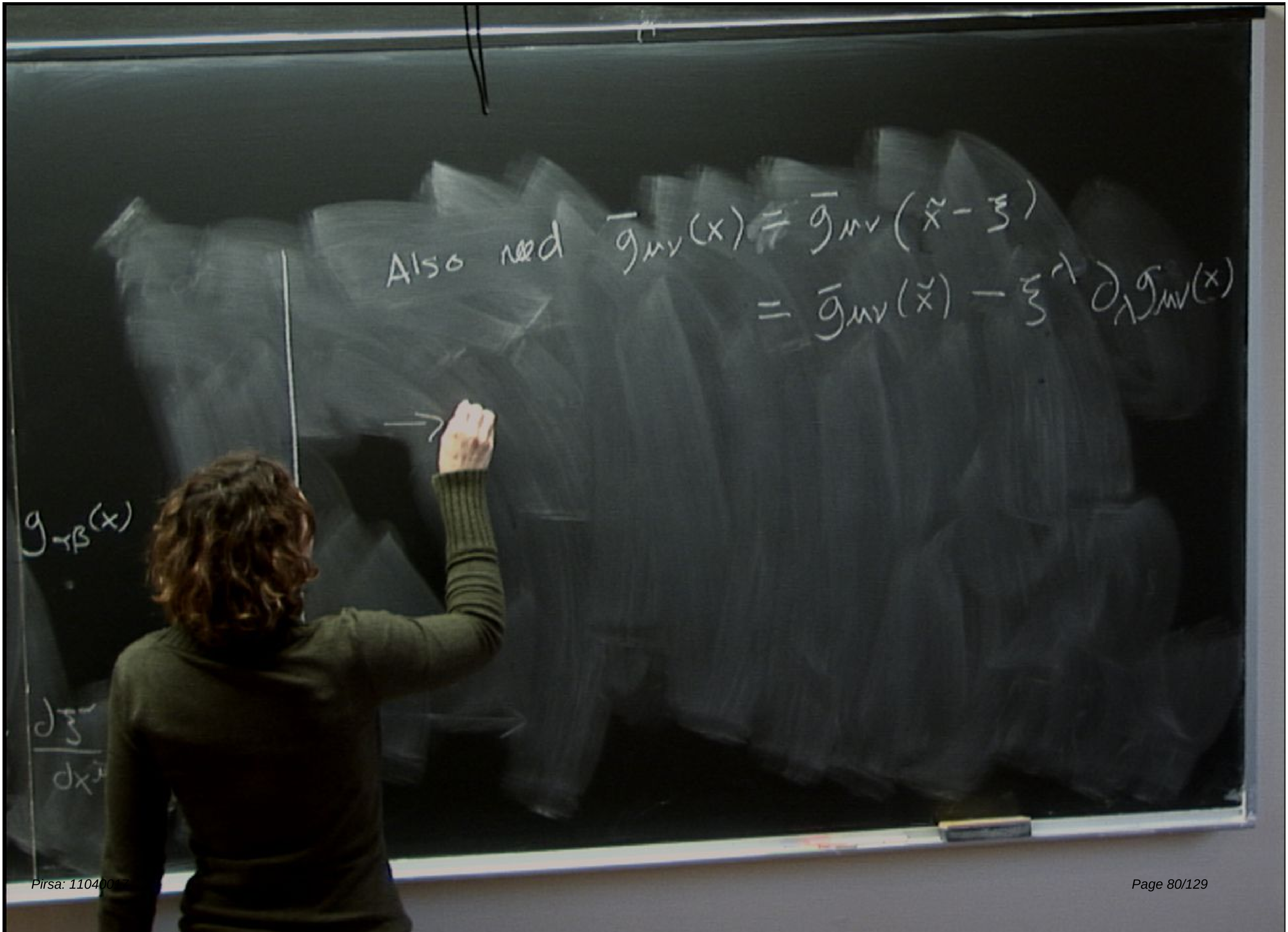
What happens to Φ, Ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)

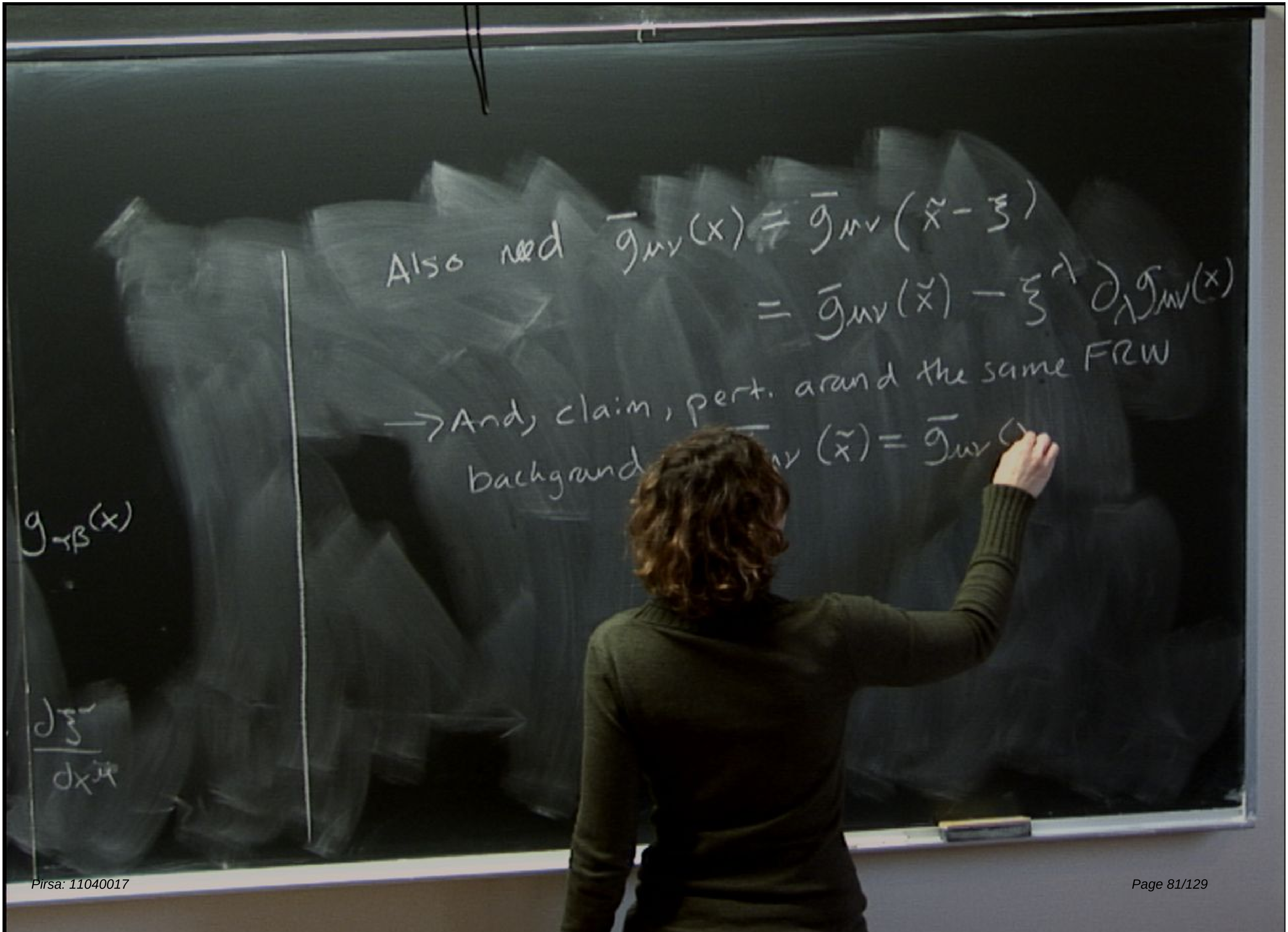
$$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu}\frac{\partial x^\beta}{\partial \tilde{x}^\nu}\, g_{\alpha\beta}(x)$$

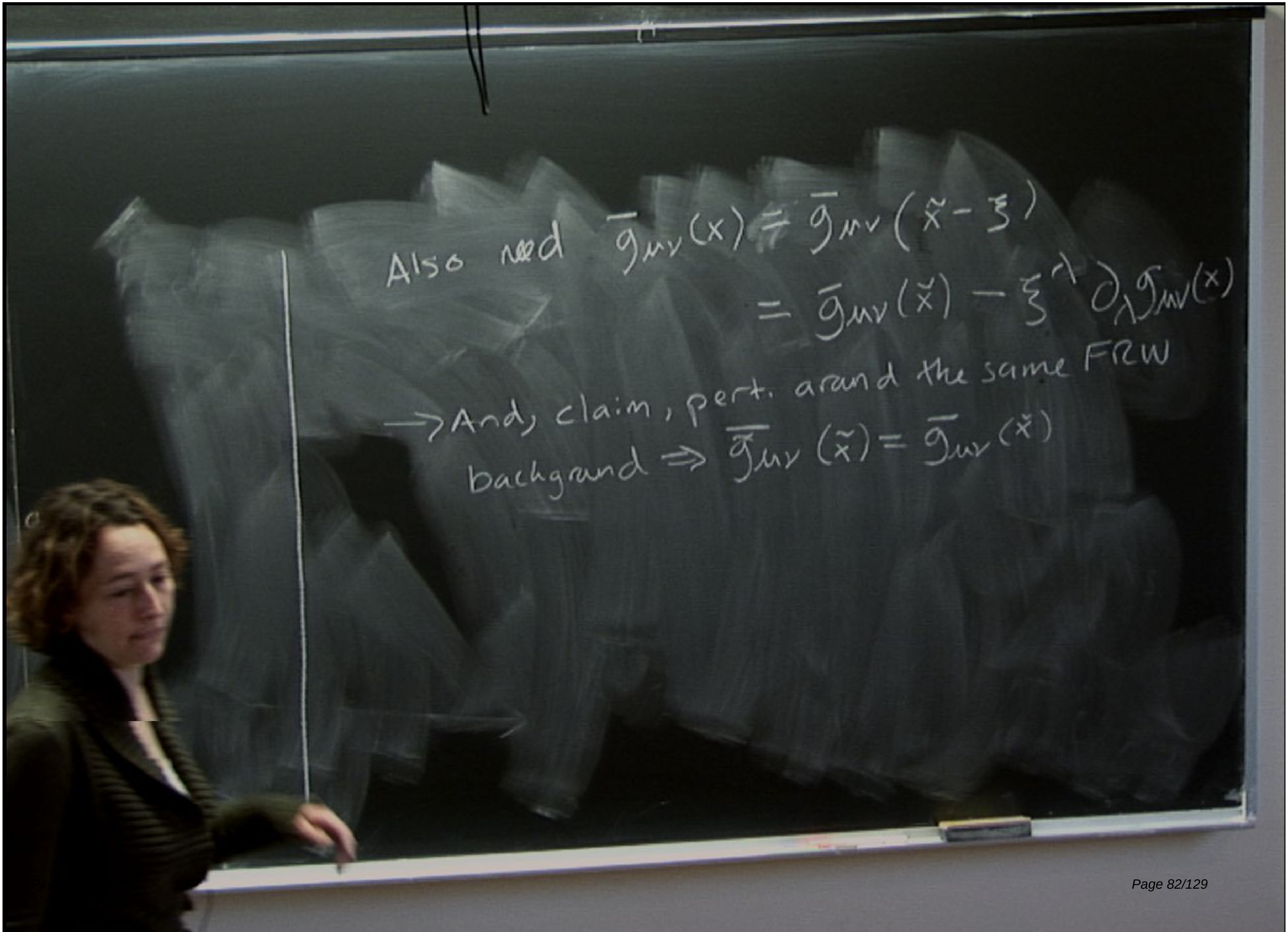
$$= \left[\delta^\alpha_\mu - \frac{\partial \xi^\alpha}{\partial \tilde{x}^\mu}\right]\left[\delta^\beta_\nu - \frac{\partial \xi^\beta}{\partial \tilde{x}^\nu}\right] g_{\alpha\beta}(x)$$

$$\bar{g}_{\mu\nu}(\tilde{x}^\mu) + \tilde{\delta} g_{\mu\nu}(\tilde{x}) \approx \underbrace{g_{\mu\nu}(x)}_{\bar{g}_{\mu\nu}(x) + \delta g_{\mu\nu}(x)} - g_{\mu\beta}\frac{\partial \xi^\beta}{\partial x^\nu} - g_{\alpha\nu}\frac{\partial \xi^\alpha}{\partial x^\mu}$$


Also need $\bar{g}_{\mu\nu}(x) \approx \bar{g}_{\mu\nu}$
$g_{\alpha\beta}(x)$
$\frac{d\xi^{\alpha}}{dx^{\mu}}$


Also need $\bar g_{\mu\nu}(x) = \bar g_{\mu\nu}(\tilde x - \xi)$
$= \bar g_{\mu\nu}(\tilde x) - \xi^{\lambda} \partial_{\lambda} g_{\mu\nu}(x)$
$g_{\alpha\beta}(x)$


Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$
$= \bar{g}_{\mu\nu}(\tilde{x}) - \xi^{\lambda}\partial_{\lambda}\bar{g}_{\mu\nu}(x)$
→ And, claim, pert. around the same FRW
background
$\bar{g}_{\mu\nu}(\tilde{x}) = \bar{g}_{\mu\nu}($
$g_{\alpha\beta}(x)$
$\frac{d\xi}{dx}$


Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$
$= \bar{g}_{\mu\nu}(\tilde{x}) - \xi^{\lambda} \partial_{\lambda} g_{\mu\nu}(x)$
→ And, claim, pert. around the same FRW
background ⇒ $\bar{g}_{\mu\nu}(\tilde{x}) = \bar{g}_{\mu\nu}(\tilde{x})$

$g_{\alpha\beta}(x)$

$\dfrac{\partial \xi^{\alpha}}{\partial x^{\mu}}$

Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$

$$= \bar{g}_{\mu\nu}(\check{x}) - \xi^{\lambda}\partial_{\lambda} g_{\mu\nu}(x)$$

$\longrightarrow$ And, claim, pert. around the same FRW background $\Rightarrow \bar{g}_{\mu\nu}(\tilde{x}) = \bar{g}_{\mu\nu}(\check{x})$

Left over

What happens to Φ, Ψ, B, E

under $x^\mu \to \tilde{x}^\mu$ (to 1st order)

$$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu}\frac{\partial x^\beta}{\partial \tilde{x}^\nu}\, g_{\alpha\beta}(x)$$

$$= \left[\delta^\alpha_\mu - \frac{\partial \xi^\alpha}{\partial \tilde{x}^\mu}\right]\left[\delta^\beta_\nu - \frac{\partial \xi^\beta}{\partial \tilde{x}^\nu}\right]$$

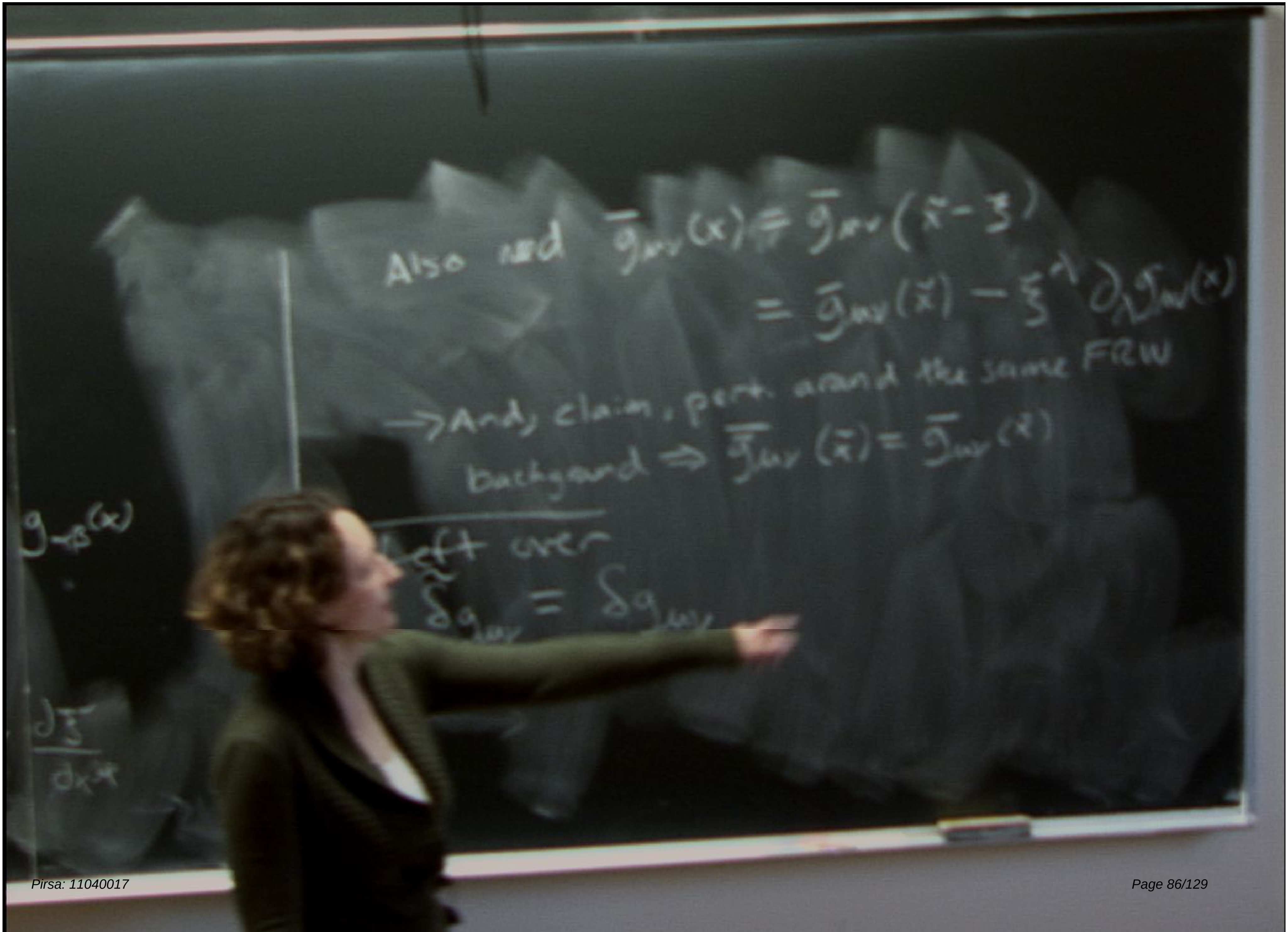
$$\cancel{\bar{g}_{\mu\nu}(\tilde{x}^\mu)} + \tilde{\delta} g_{\mu\nu}(\tilde{x}) \approx \underbrace{g_{\mu\nu}(x)}_{\bar{g}_{\mu\nu}(x) + \delta g_{\mu\nu}(x)} - g_{\mu\beta}\frac{\partial \xi^\beta}{\partial x^\nu} - g_{\alpha\nu}$$

What happens to Φ, Ψ, B, E
under $x^\mu \to \tilde{x}^\mu$ (to 1st order)

$$\tilde{g}_{\mu\nu}(\tilde{x}^\mu) = \frac{\partial x^\alpha}{\partial \tilde{x}^\mu} \frac{\partial x^\beta}{\partial \tilde{x}^\nu} g_{\alpha\beta}(x)$$

$$= \left[\delta^\alpha_\mu - \frac{\partial \xi^\alpha}{\partial \tilde{x}^\mu}\right]\left[\delta^\beta_\nu - \frac{\partial \xi^\beta}{\partial \tilde{x}^\nu}\right] g_{\alpha\beta}(x)$$

$$\cancel{\bar{g}_{\mu\nu}(\tilde{x}^\mu)} + \tilde{\delta} g_{\mu\nu}(\tilde{x}) \approx \underbrace{g_{\mu\nu}(x)}_{\bar{g}_{\mu\nu}(x) + \delta g_{\mu\nu}(x)} - g_{\mu\beta}\frac{\partial \xi^\beta}{\partial x^\nu} - g_{\alpha\nu}\frac{\partial \xi^\alpha}{\partial x^\mu}$$



Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$
$= \bar{g}_{\mu\nu}(\tilde{x}) - \xi^{\lambda} \partial_{\lambda} \bar{g}_{\mu\nu}(x)$
$\rightarrow$ And, claim, pert. around the same FRW
background $\Rightarrow \bar{g}_{\mu\nu}(\tilde{x}) = \bar{g}_{\mu\nu}(x)$
left over
$\tilde{\delta g}_{\mu\nu} = \delta g_{\mu\nu}$

$g_{\alpha\beta}(x)$

dx^μ

Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$

$= \bar{g}_{\mu\nu}(\tilde{x}) - \xi^\lambda \partial_\lambda g_{\mu\nu}(x)$

$\rightarrow$ And, claim, pert. around the same FRW

background $\Rightarrow \bar{g}_{\mu\nu}(\tilde{x}) = \bar{g}_{\mu\nu}(\tilde{x})$

Left over

$\tilde{\delta} g_{\mu\nu} = \delta g_{\mu\nu} - \xi^\lambda \partial_\lambda \bar{g}_{\mu\nu}$

$g_{\alpha\beta}(x)$

$\frac{d\xi^\alpha}{dx^\mu}$

Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$

$= \bar{g}_{\mu\nu}(\tilde{x}) - \xi^\lambda \partial_\lambda g_{\mu\nu}(x)$

$\rightarrow$ And, claim, pert. around the same FRW background $\Rightarrow \bar{\tilde{g}}_{\mu\nu}(\tilde{x}) = \bar{g}_{\mu\nu}(\tilde{x})$

Left over

$$\boxed{\widetilde{\delta g}_{\mu\nu} = \delta g_{\mu\nu} - \xi^\lambda \partial_\lambda \bar{g}_{\mu\nu} - \bar{g}_{\mu\beta}\frac{d\xi^\beta}{dx^\nu} - \bar{g}_{\alpha\nu}\frac{d\xi^\alpha}{dx^\mu}}$$

Let's work out $\delta\tilde{g}_{00}$

$$\delta\tilde{g}_{00} = -2a^2\Phi$$

$$a^2\Big[-(1+2\phi)d\eta^2 - 2B_{,i}\,dx^i d\eta + \left[(1-2\psi)\delta_{ij} - 2E_{,ij}\right]dx^i dx^j\Big]$$

...dinate transformation

infinitesimal

$$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$$

...ition (Spatial) $\xi^i = \xi^i_\perp + \partial^i \zeta$

$\partial_i(\xi^i_\perp) = 0$

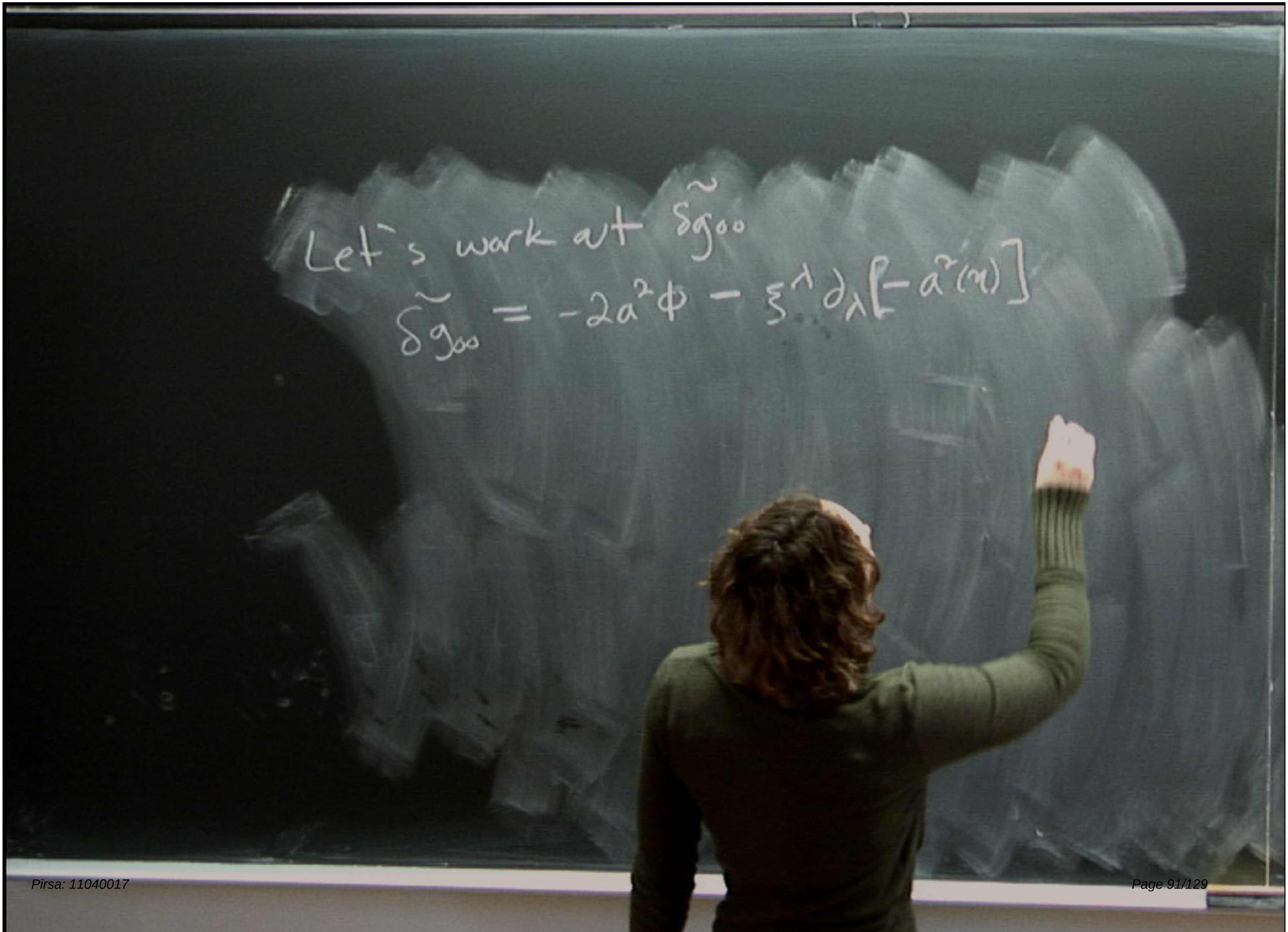
scalar

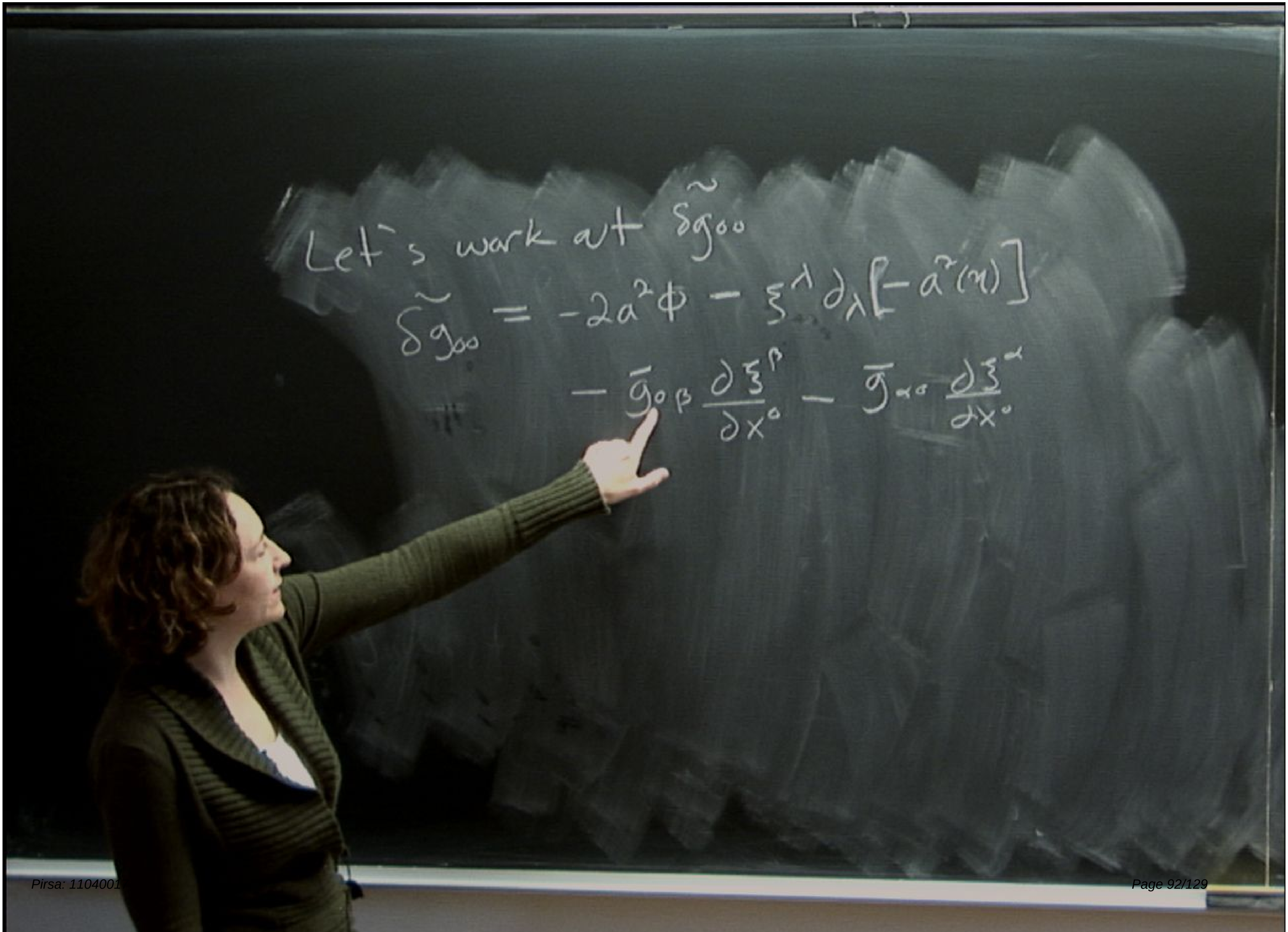
Focus on Scalars

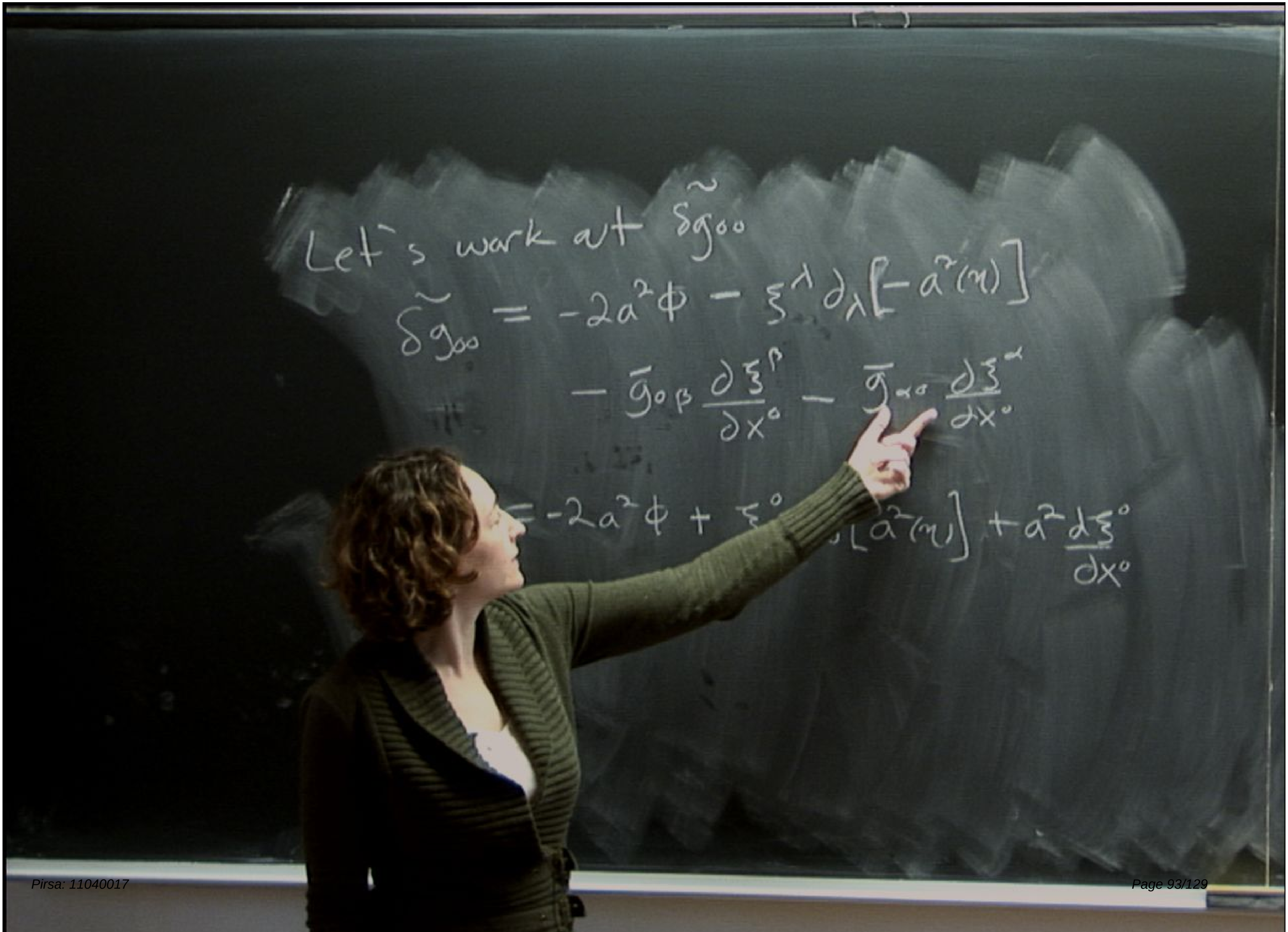
↪ what about freedom to change coordinates?

$\longrightarrow g_{\mu\nu} = \bar{g}_{\mu\nu} + h_{\mu\nu}$

FRW


Let's work at $\delta\tilde{g}_{00}$
$\delta\tilde{g}_{00} = -2a^2\phi - \xi^\lambda \partial_\lambda[-a^2(\eta)]$


Let's work at $\delta\tilde{g}_{00}$
$\delta\tilde{g}_{00} = -2a^2\Phi - \xi^\lambda \partial_\lambda[-a^2(\eta)]$
$- \bar{g}_{0\beta}\frac{\partial\xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial\xi^\alpha}{\partial x^0}$


Let's work at $\delta\tilde{g}_{00}$
$\delta\tilde{g}_{00} = -2a^2\phi - \xi^\lambda\partial_\lambda[-a^2(\eta)]$
$- \bar{g}_{0\beta}\frac{\partial\xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial\xi^\alpha}{\partial x^0}$
$= -2a^2\phi + \xi^0$
$[a^2(\eta)] + a^2\frac{\partial\xi^0}{\partial x^0}$

Let's work at $\delta\tilde{g}_{00}$

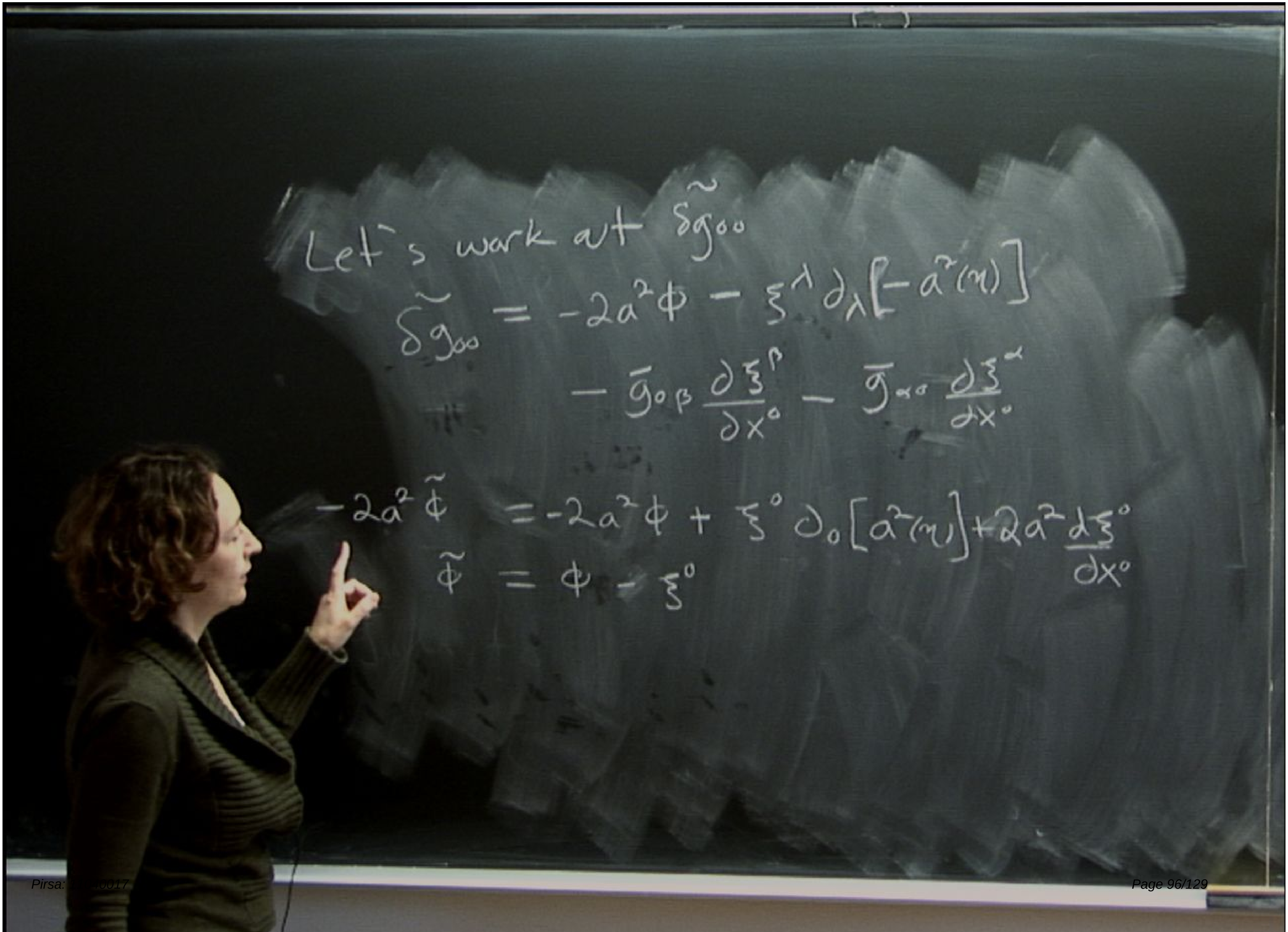
$$\delta\tilde{g}_{00} = -2a^2\phi - \xi^\lambda \partial_\lambda\left[-a^2(\eta)\right] - \bar{g}_{0\beta}\frac{\partial \xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial \xi^\alpha}{\partial x^0}$$

$$-2a \quad = -2a^2\phi + \xi^0\partial_0\left[a^2(\eta)\right] + 2a^2\frac{\partial \xi^0}{\partial x^0}$$

Let's work at $\delta \tilde{g}_{00}$

$$\delta \tilde{g}_{00} = -2a^2\Phi - \xi^\lambda \partial_\lambda[-a^2(\eta)] - \bar{g}_{0\beta}\frac{\partial \xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial \xi^\alpha}{\partial x^0}$$

$$-2a^2\tilde{\Phi} = -2a^2\Phi + \xi^0 \partial_0[a^2(\eta)] + 2a^2\frac{\partial \xi^0}{\partial x^0}$$


Let's work at $\delta\tilde{g}_{00}$
$\delta\tilde{g}_{00} = -2a^2\phi - \xi^\lambda\partial_\lambda[-a^2(\eta)]$
$- \bar{g}_{0\beta}\frac{\partial\xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial\xi^\alpha}{\partial x^0}$
$-2a^2\tilde{\phi} = -2a^2\phi + \xi^0\partial_0[a^2(\eta)] + 2a^2\frac{\partial\xi^0}{\partial x^0}$
$\tilde{\phi} = \phi - \xi^0$

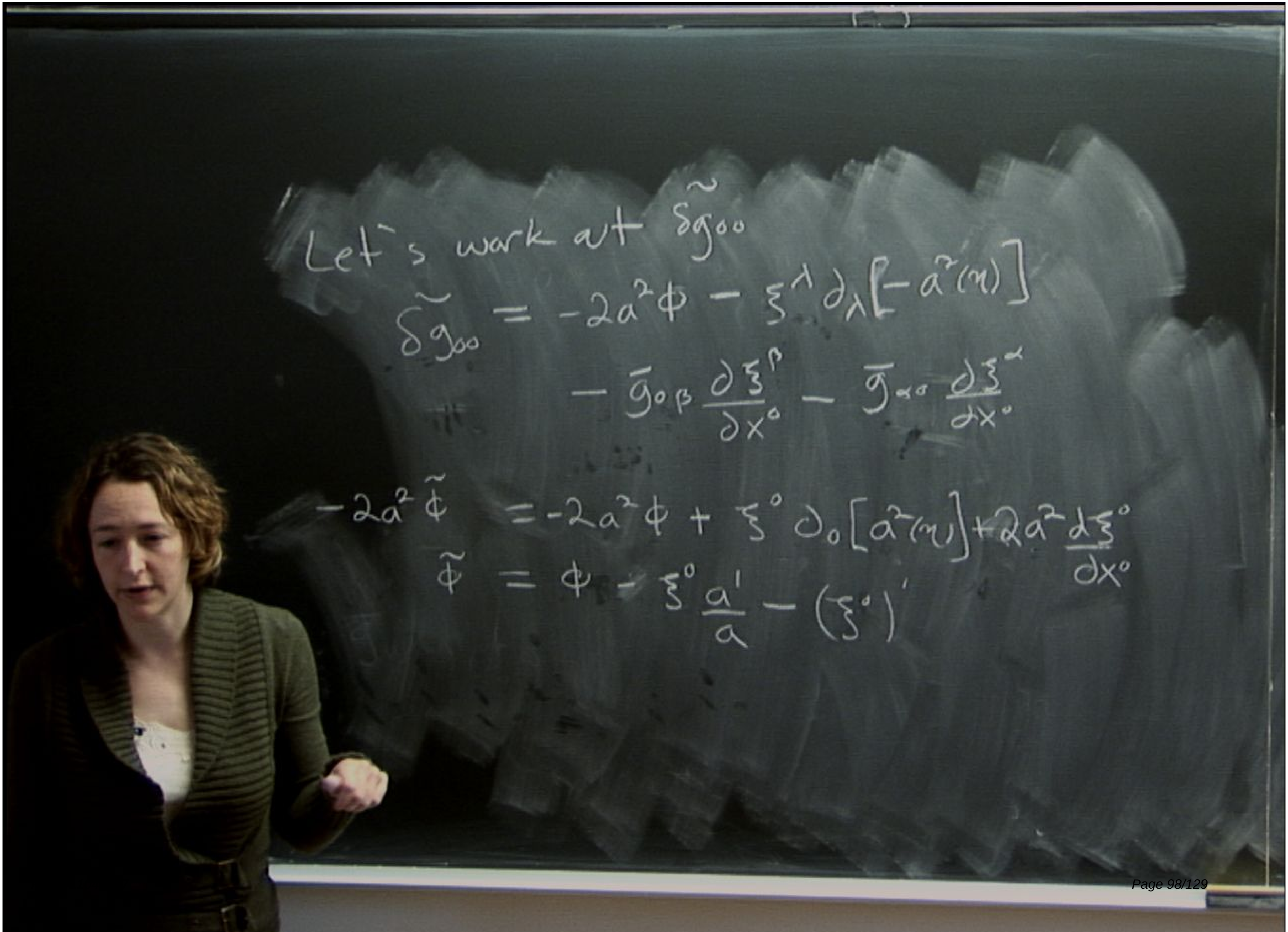
Let's work at $\delta \tilde{g}_{00}$

$$\delta \tilde{g}_{00} = -2a^2\Phi - \xi^\lambda \partial_\lambda\left[-a^2(\eta)\right]$$

$$- \bar{g}_{0\beta}\frac{\partial \xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial \xi^\alpha}{\partial x^0}$$

$$-2a^2\tilde{\Phi} = -2a^2\Phi + \xi^0 \partial_0\left[a^2(\eta)\right] + 2a^2\frac{\partial \xi^0}{\partial x^0}$$

$$\tilde{\Phi} = \Phi - \xi^0 \frac{a'}{a}$$


Let's work at $\widetilde{\delta g_{00}}$
$\widetilde{\delta g_{00}} = -2a^2\phi - \xi^\lambda \partial_\lambda[-a^2(\eta)]$
$- \bar{g}_{0\beta}\frac{\partial \xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial \xi^\alpha}{\partial x^0}$
$-2a^2\tilde{\phi} = -2a^2\phi + \xi^0 \partial_0[a^2(\eta)] + 2a^2\frac{d\xi^0}{dx^0}$
$\tilde{\phi} = \phi - \xi^0\frac{a'}{a} - (\xi^0)'$

Let's work at $\widetilde{\delta g_{00}}$

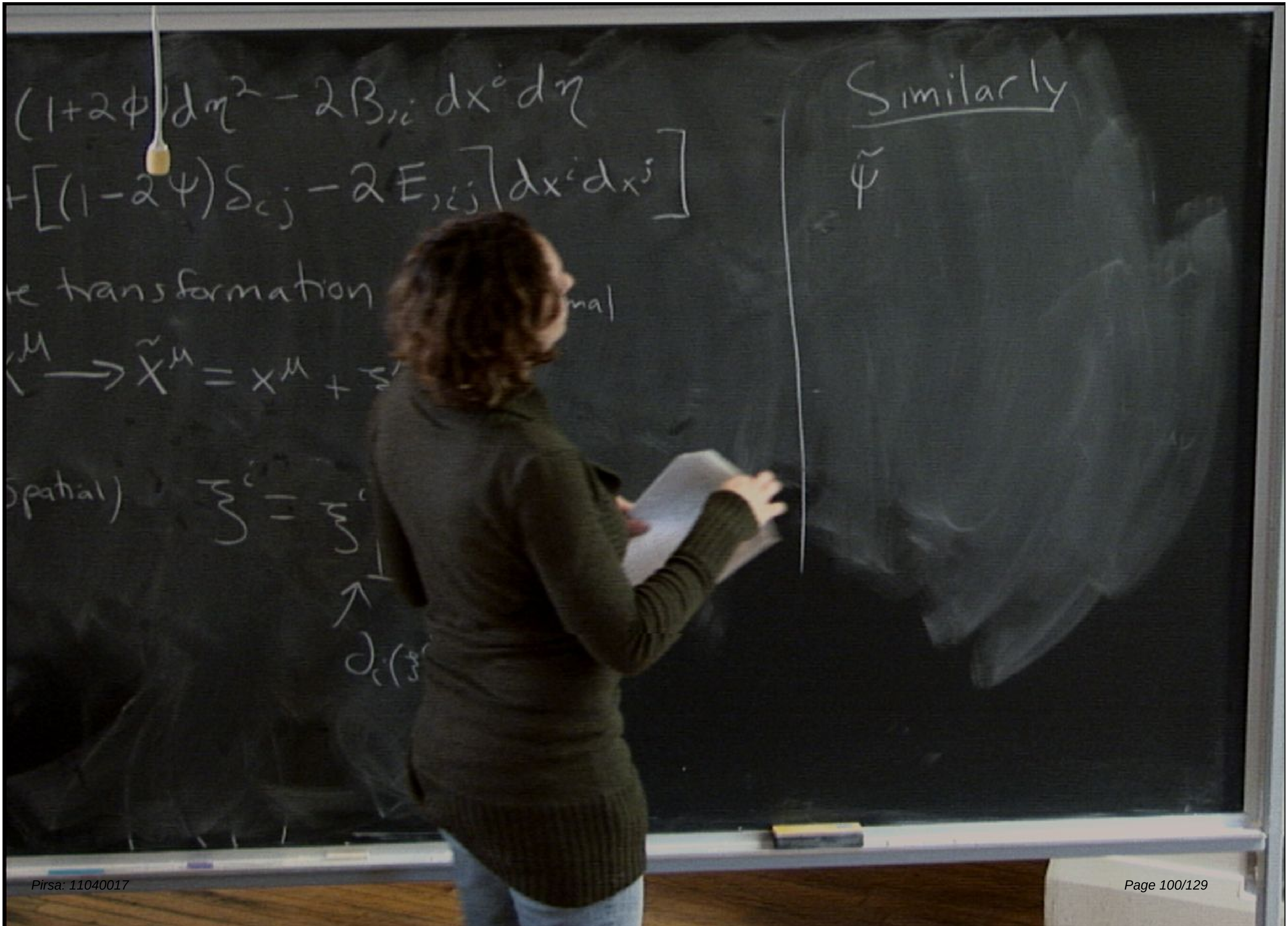
$$\widetilde{\delta g_{00}} = -2a^2\phi - \xi^\lambda \partial_\lambda\left[-a^2(\eta)\right]$$

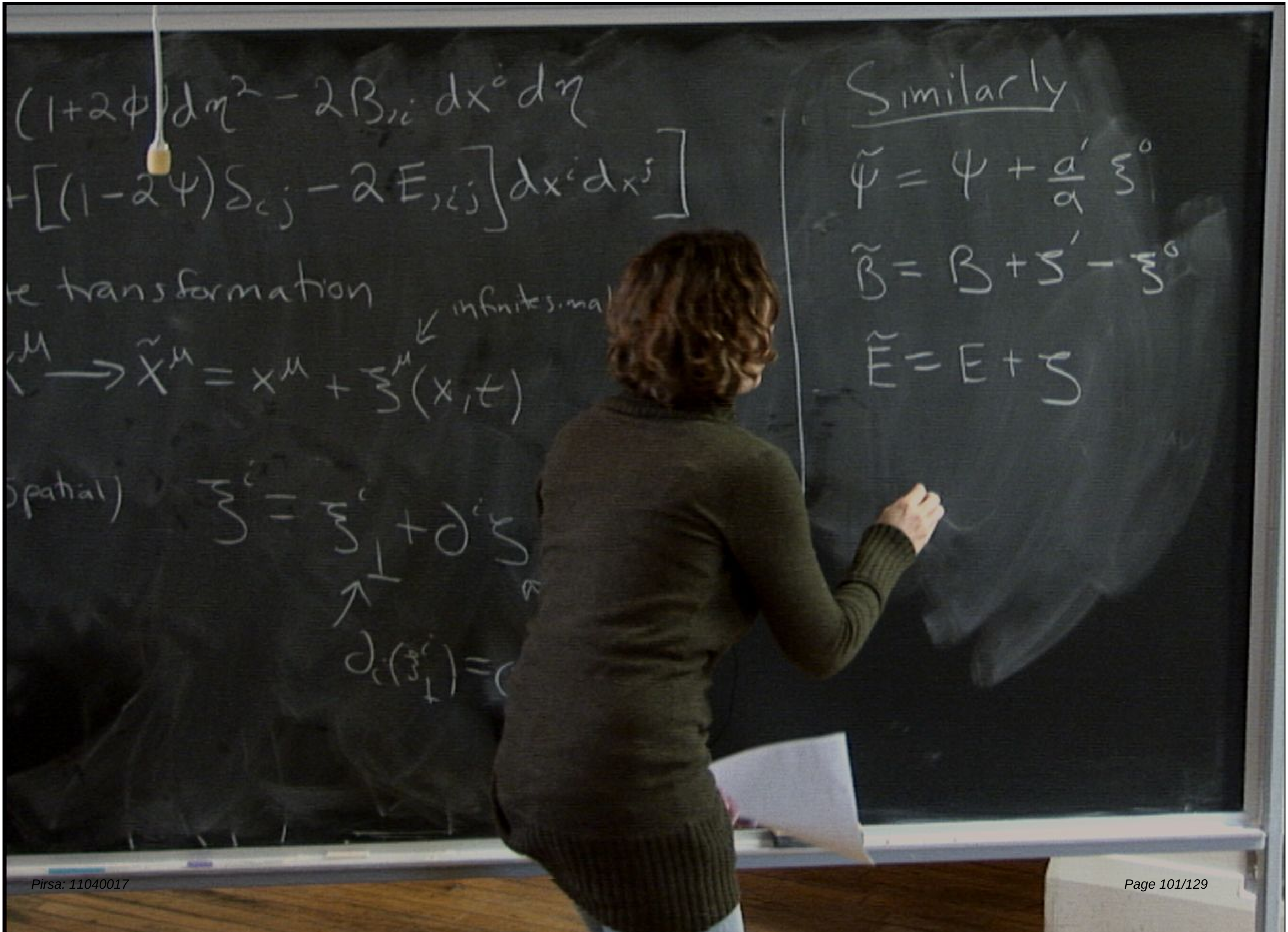
$$- \bar{g}_{0\beta}\frac{\partial \xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial \xi^\alpha}{\partial x^0}$$

$$-2a^2\tilde{\phi} = -2a^2\phi + \xi^0 \partial_0\left[a^2(\eta)\right] + 2a^2\frac{d\xi^0}{dx^0}$$

$$\tilde{\phi} = \phi - \xi^0\frac{a'}{a} - (\xi^0)'$$

$$\boxed{\tilde{\Phi} = \phi - \frac{1}{a}(a\xi^0)'}$$


(1+2φ)dη² − 2B,i dx^i dη
+[(1−2ψ)δij − 2E,ij]dx^i dx^j]
te transformation
mal
x^μ → x̃^μ = x^μ + ξ
spatial) ξ^i = ξ^i
⊥
∂i(ξ
Similarly
ψ̃


$(1+2\phi)d\eta^2 - 2B_{,i}\,dx^i d\eta$
$+[(1-2\psi)\delta_{ij} - 2E_{,ij}]dx^i dx^j]$
te transformation
infinitesimal
$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$
(spatial)
$\xi^i = \xi^i_\perp + \partial^i \zeta$
$\partial_i(\xi^i_\perp) = 0$
Similarly
$\tilde{\psi} = \psi + \frac{a'}{a}\xi^0$
$\tilde{B} = B + \zeta' - \xi^0$
$\tilde{E} = E + \zeta$

$(1+2\phi)\, d\eta^2 - 2B_{,i}\, dx^i d\eta$

$+ \left[(1-2\psi)\delta_{ij} - 2E_{,ij}\right] dx^i dx^j \Big]$

transformation

infinitesimal

$\longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$

tial)

$\xi^i = \xi^i_\perp + \partial^i \xi$

$\partial_i(\xi^i_\perp) = 0$

scalar

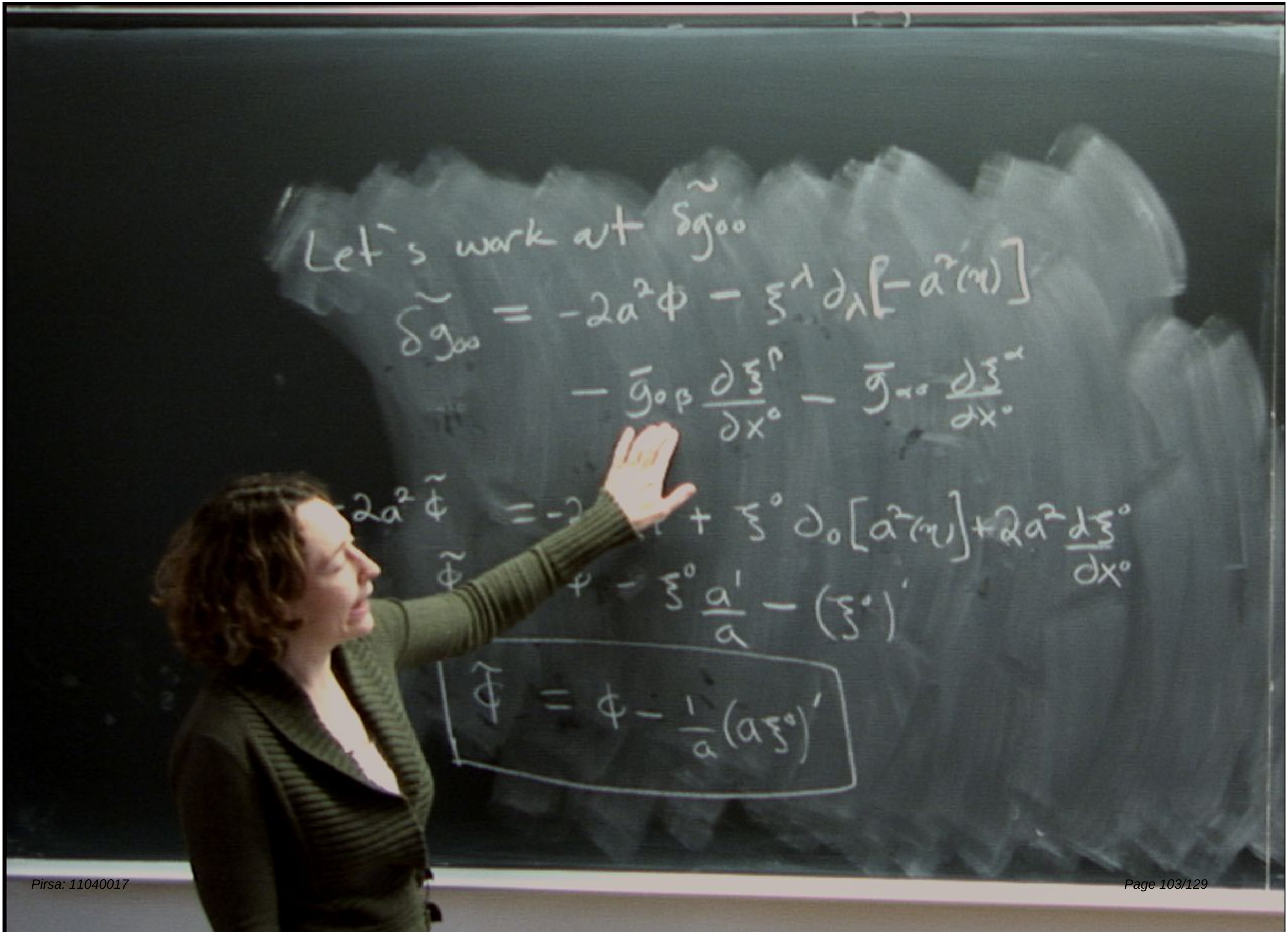
Similarly

$\tilde{\psi} = \psi + \frac{a'}{a}\xi^0$

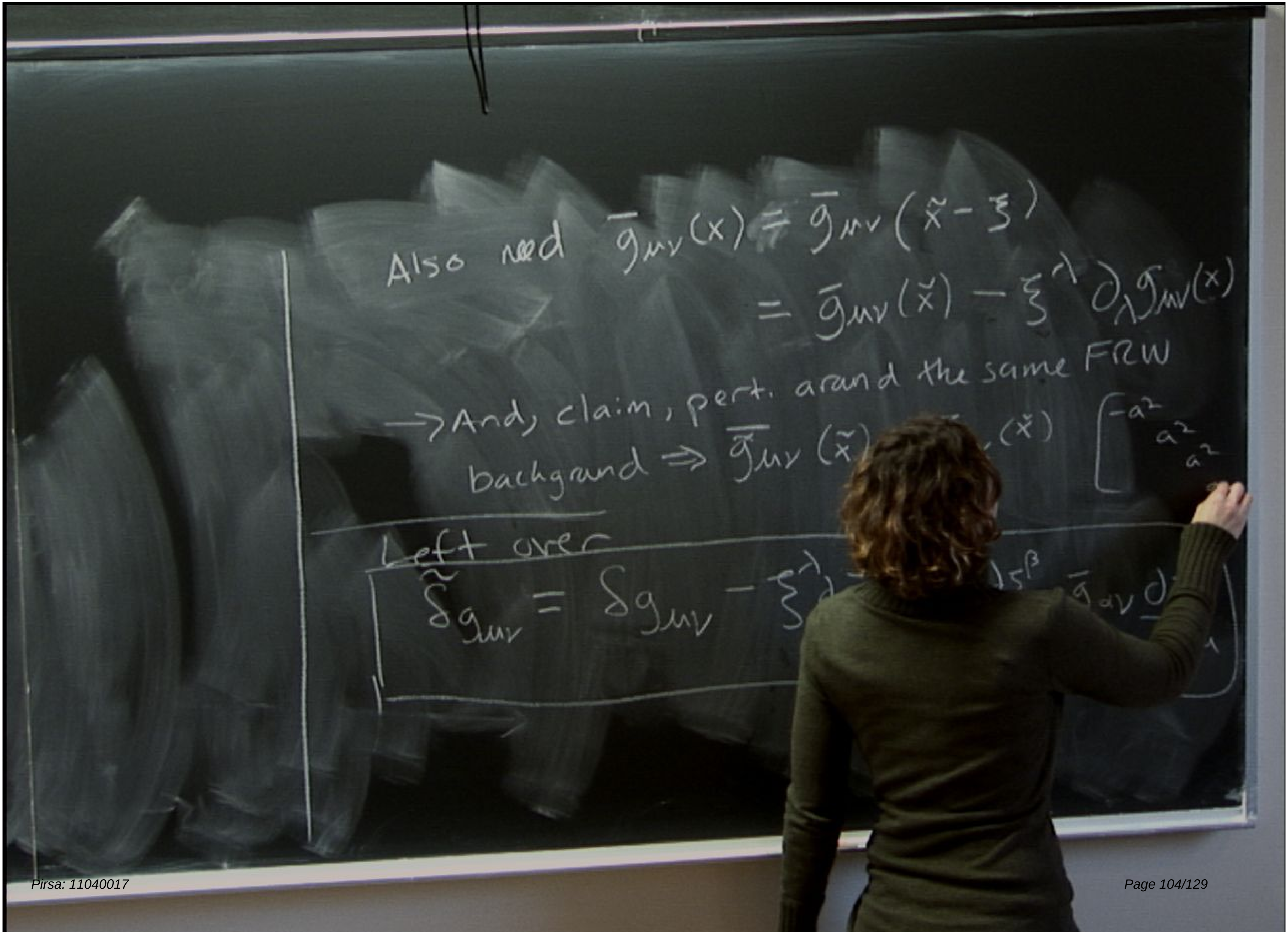
$\tilde{B} = B + \xi' - \xi^0$

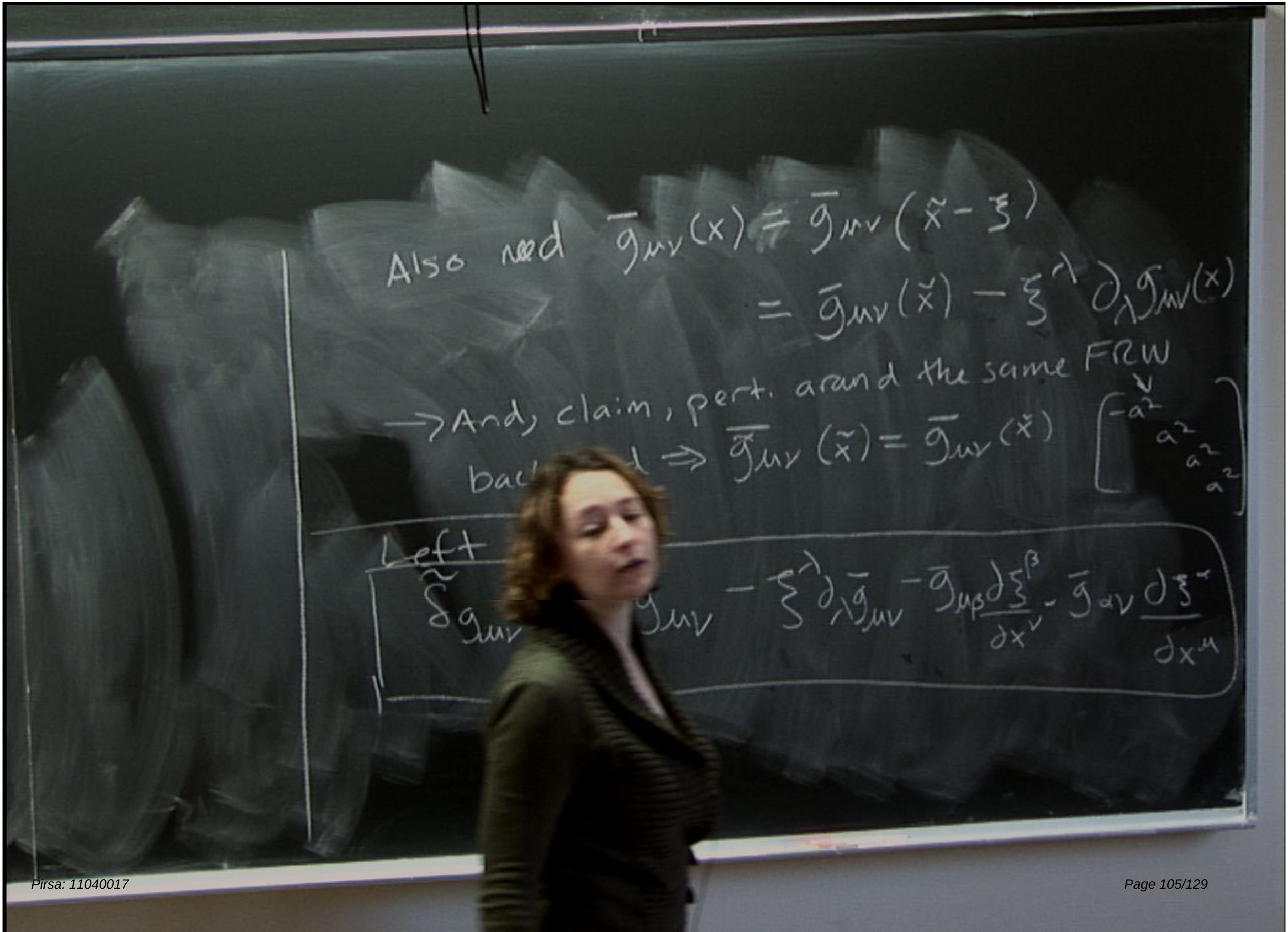
$\tilde{E} = E + \xi$

$\tilde{\phi} = \phi - \frac{1}{a}(a\xi^0)'$



Let's work at $\delta\tilde{g}_{00}$
$\delta\tilde{g}_{00} = -2a^2\phi - \xi^\lambda \partial_\lambda[-a^2(\eta)]$
$- \bar{g}_{0\beta}\frac{\partial\xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial\xi^\alpha}{\partial x^0}$
$-2a^2\tilde{\phi} = -2 \quad + \xi^0\partial_0[a^2(\eta)] + 2a^2\frac{d\xi^0}{dx^0}$
$\tilde{\phi} \quad \phi - \xi^0\frac{a'}{a} - (\xi^0)'$
$\boxed{\tilde{\phi} = \phi - \frac{1}{a}(a\xi^0)'}$


Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$
$= \bar{g}_{\mu\nu}(\tilde{x}) - \xi^{\lambda}\partial_{\lambda}\bar{g}_{\mu\nu}(x)$
→ And, claim, pert. around the same FRW
background ⇒ $\bar{\tilde{g}}_{\mu\nu}(\tilde{x})$
Left over
$\tilde{\delta} g_{\mu\nu} = \delta g_{\mu\nu} - \xi^{\lambda}$


Also need $\bar{g}_{\mu\nu}(x) = \bar{g}_{\mu\nu}(\tilde{x} - \xi)$
$= \bar{g}_{\mu\nu}(\tilde{x}) - \xi^{\lambda}\partial_\lambda g_{\mu\nu}(x)$
→ And, claim, pert. around the same FRW
background ⇒ $\bar{g}_{\mu\nu}(\tilde{x}) = \bar{g}_{\mu\nu}(\tilde{x})$
$-a^2$ a^2 a^2 a^2
Left
$\tilde{\delta} g_{\mu\nu}$ $g_{\mu\nu} - \xi^{\lambda}\partial_\lambda \bar{g}_{\mu\nu} - \bar{g}_{\mu\beta}\frac{d\xi^\beta}{dx^\nu} - \bar{g}_{\alpha\nu}\frac{d\xi^\alpha}{dx^\mu}$

$$a^2\Big[-(1+2\phi)\,d\eta^2 - 2B_{,i}\,dx^i\,d\eta$$
$$+\big[(1-2\psi)\delta_{ij} - 2E_{,ij}\big]dx^i dx^j\Big]$$

dinate transformation

infinitesimal

$$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$$

ition (Spatial) $\xi^i = \xi^i_\perp + \partial^i \xi$

$\partial_i(\xi^i_\perp) = 0$

scalar

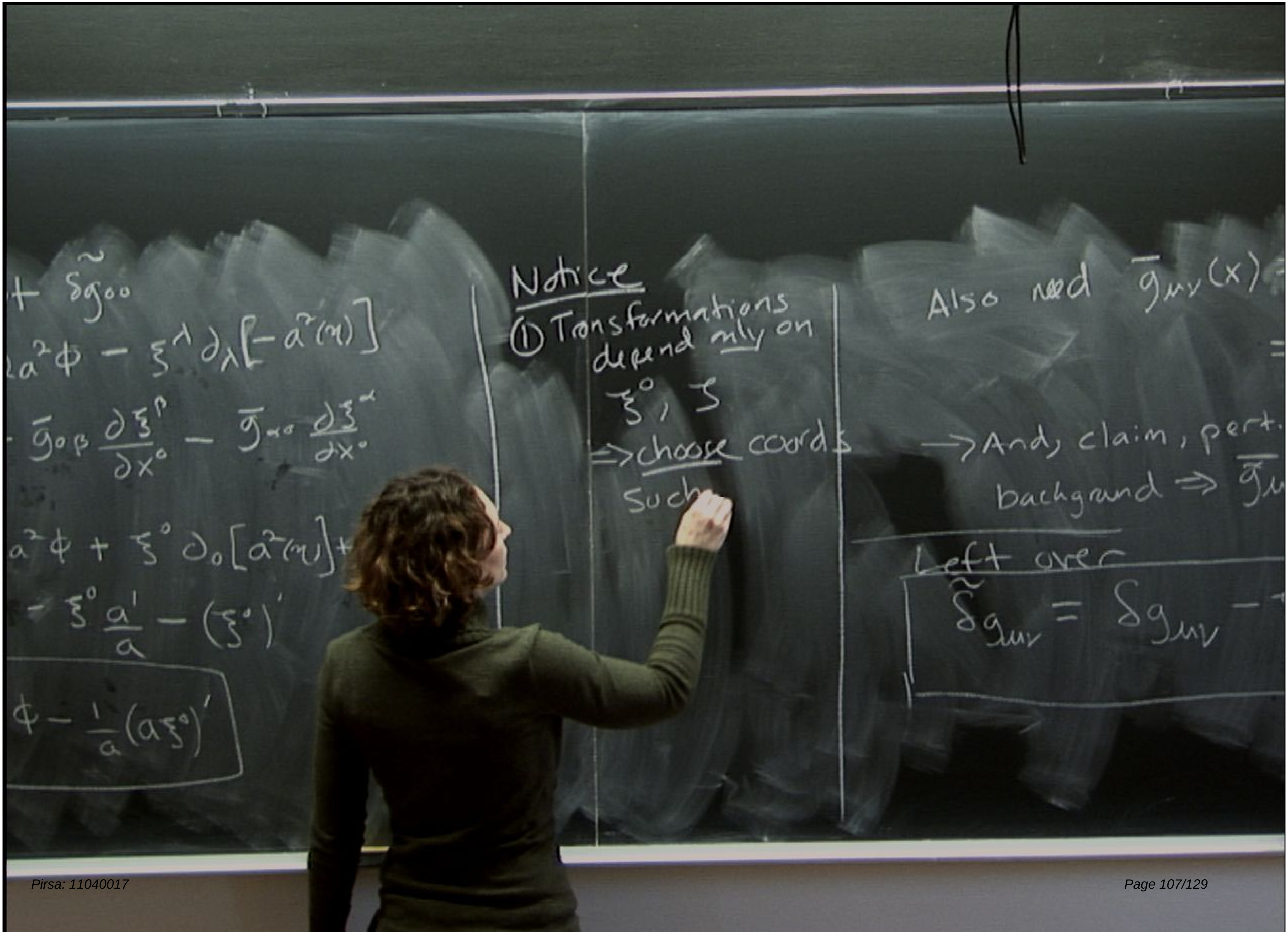
Similarly

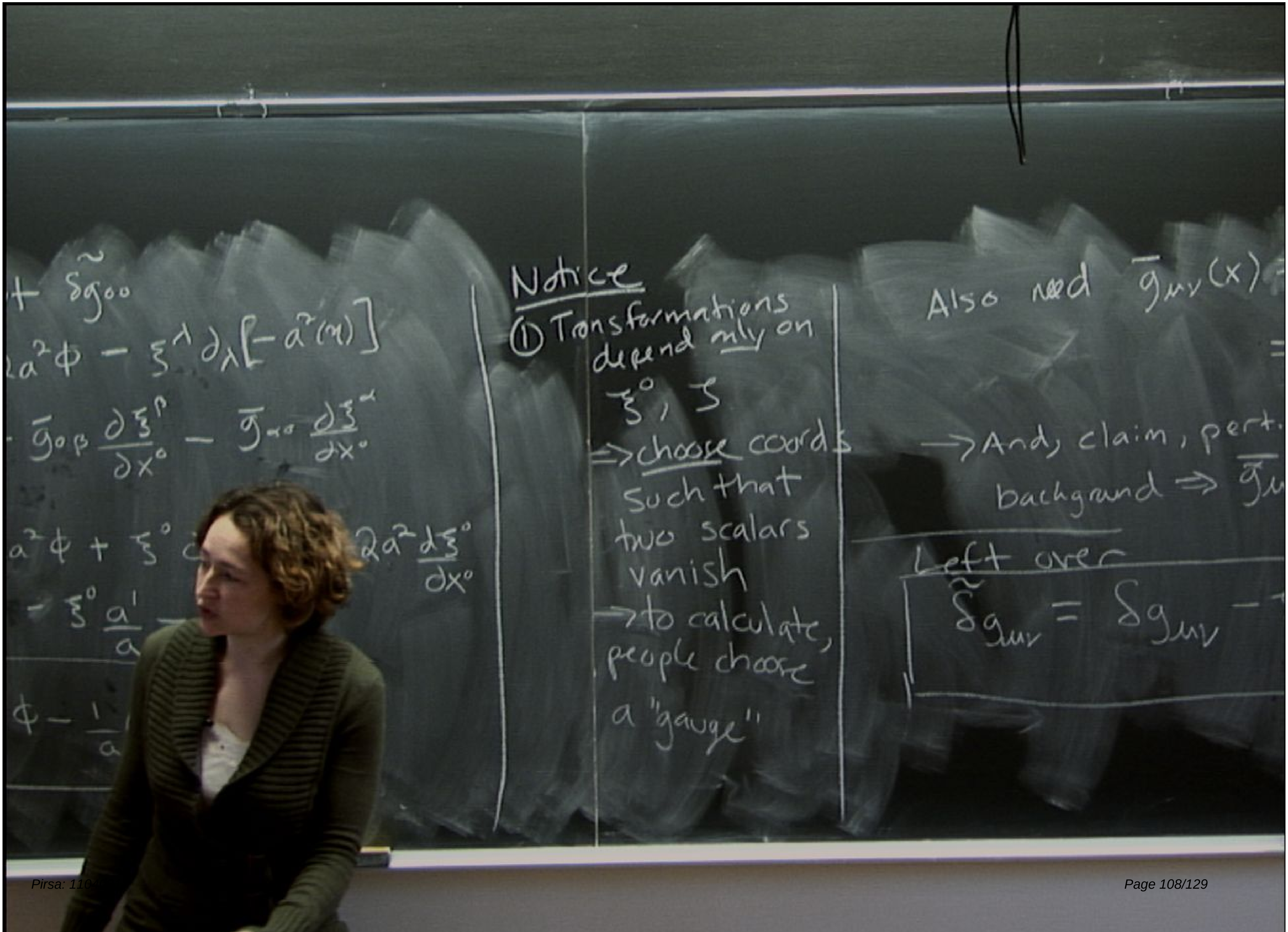
$$\tilde{\psi} = \psi + \frac{a'}{a}\xi^0$$

$$\tilde{B} = B + \xi' - \xi^0$$

$$\tilde{E} = E + \xi$$

$$\tilde{\phi} = \phi - \frac{1}{a}(a\xi^0)'$$


Notice
① Transformations depend only on
ξ°, ξ
⇒ choose coords such
Also need ḡμν(x)
→ And, claim, pert.
background ⇒ ḡμ
Left over
δ̃gμν = δgμν −


+ δg̃00
Notice
① Transformations depend only on
ξ0, ξ
⇒ choose coords such that two scalars vanish
→ to calculate, people choose a "gauge"
Also need ḡμν(x)
→ And, claim, pert.
background ⇒
Left over
δg̃μν = δgμν −

$+ \delta\tilde{g}_{00}$

$2a^2\phi - \xi^\lambda \partial_\lambda[-a^2(\eta)]$

$- \bar{g}_{0\beta}\frac{\partial \xi^\beta}{\partial x^0} - \bar{g}_{\alpha 0}\frac{\partial \xi^\alpha}{\partial x^0}$

$a^2\phi + \xi^0 \partial_0[a^2(\eta)] + 2a^2\frac{d\xi^0}{dx^0}$

$- \xi^0 \frac{a'}{a} - (\xi^0)'$

$\boxed{\phi - \frac{1}{a}(a\xi^0)'}$

Notice

(1) Transformations depend only on ξ^0, ξ

$\Rightarrow$ choose coords such that two scalars vanish

$\rightarrow$ to calculate, people choose a "gauge"

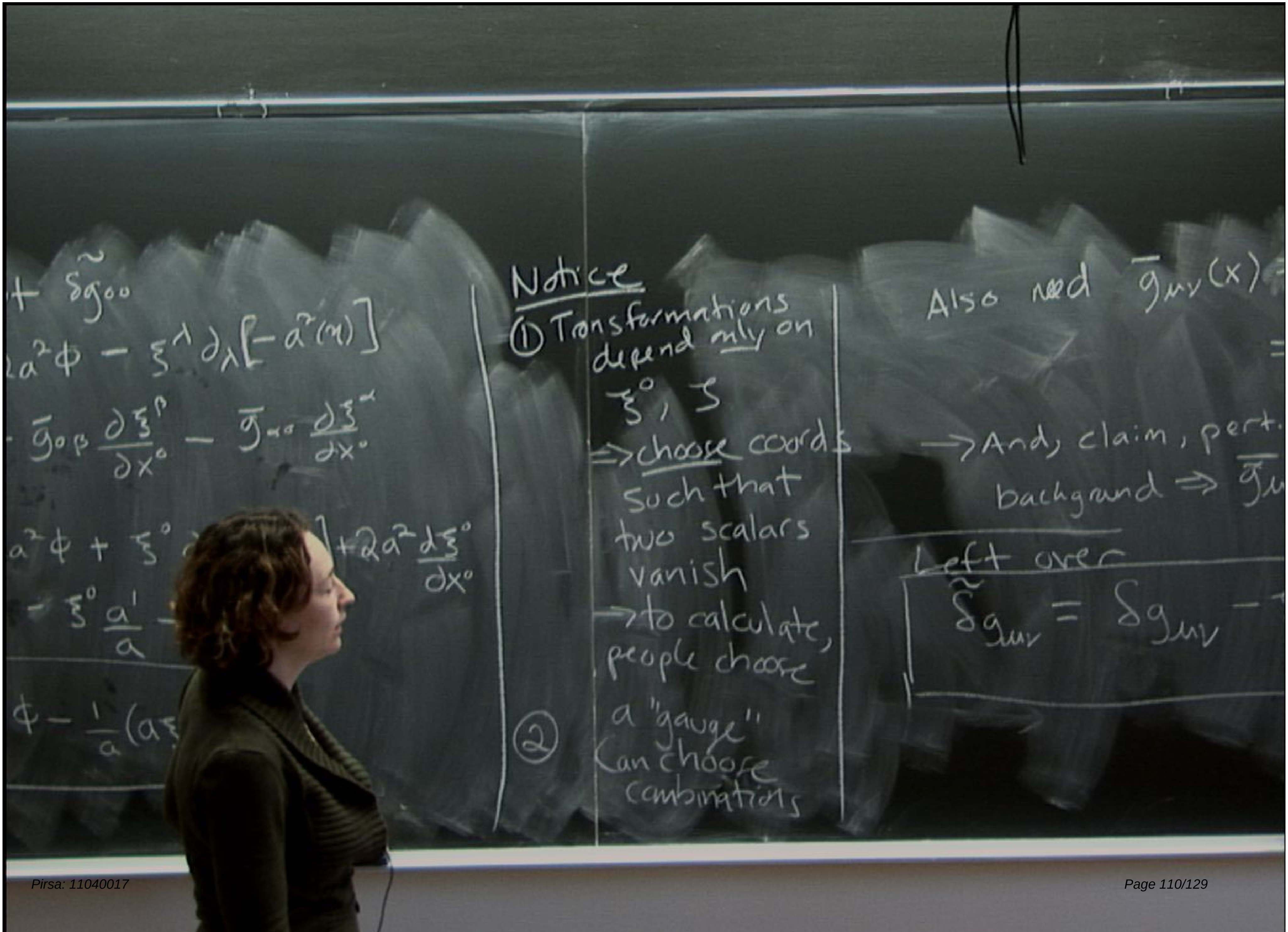
(2)

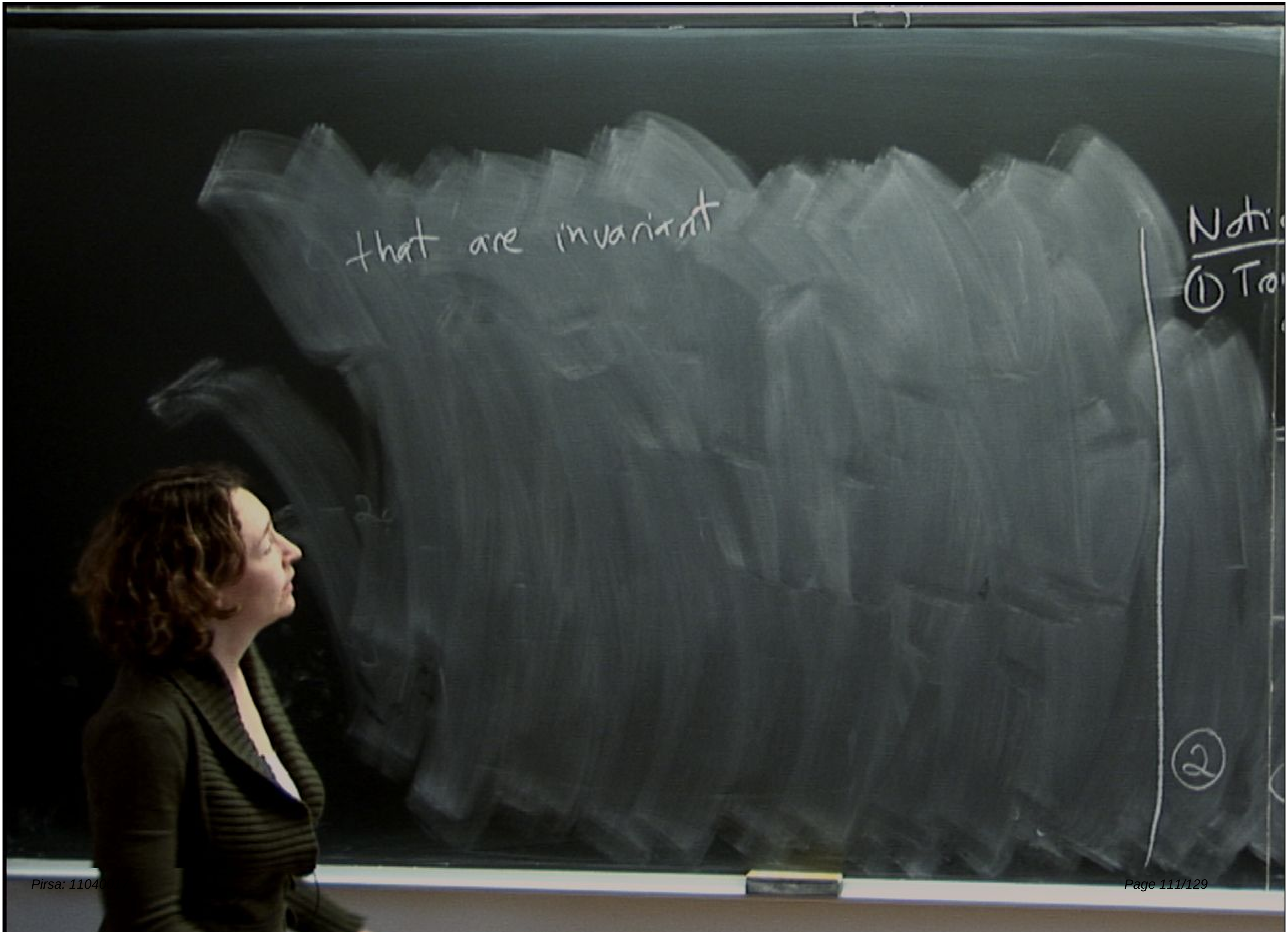
Also need $\bar{g}_{\mu\nu}(x)$

$\rightarrow$ And, claim, pert. background $\Rightarrow \bar{g}_{\mu\nu}$

Left over

$\boxed{\delta\tilde{g}_{\mu\nu} = \delta g_{\mu\nu} - }$


Notice
① Transformations depend only on ξ^0, ξ
⇒ choose coords such that two scalars vanish
→ to calculate, people choose a "gauge"
② Can choose combinations
Also need $\bar{g}_{\mu\nu}(x)$
→ And, claim, pert.
background ⇒ $\bar{g}$
Left over
$\tilde{\delta g}_{\mu\nu} = \delta g_{\mu\nu} -$



that are invariant

that are invariant

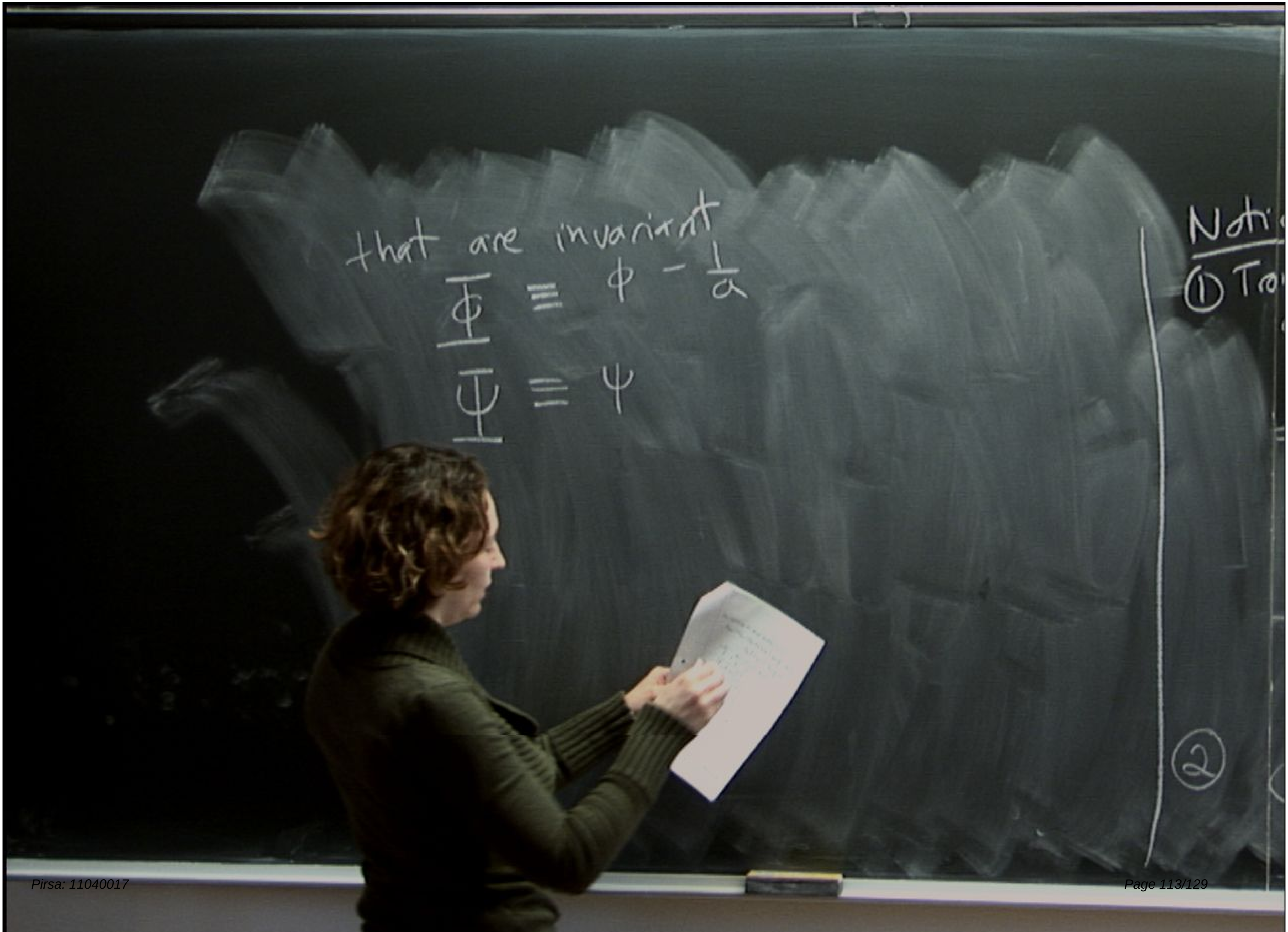
$\overline{\underline{\Phi}} \equiv$

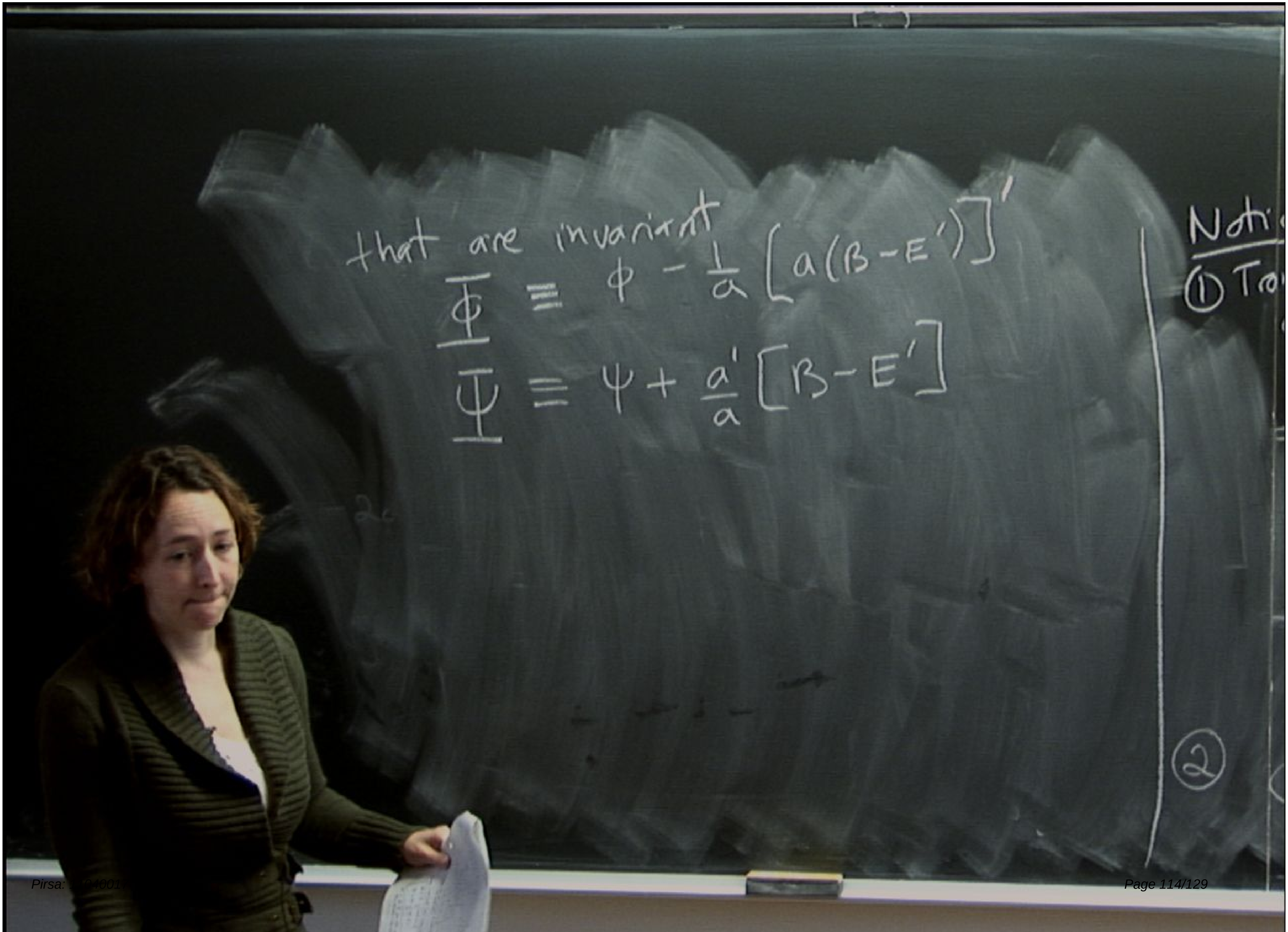
$\overline{\underline{\Psi}} \equiv$

Noti

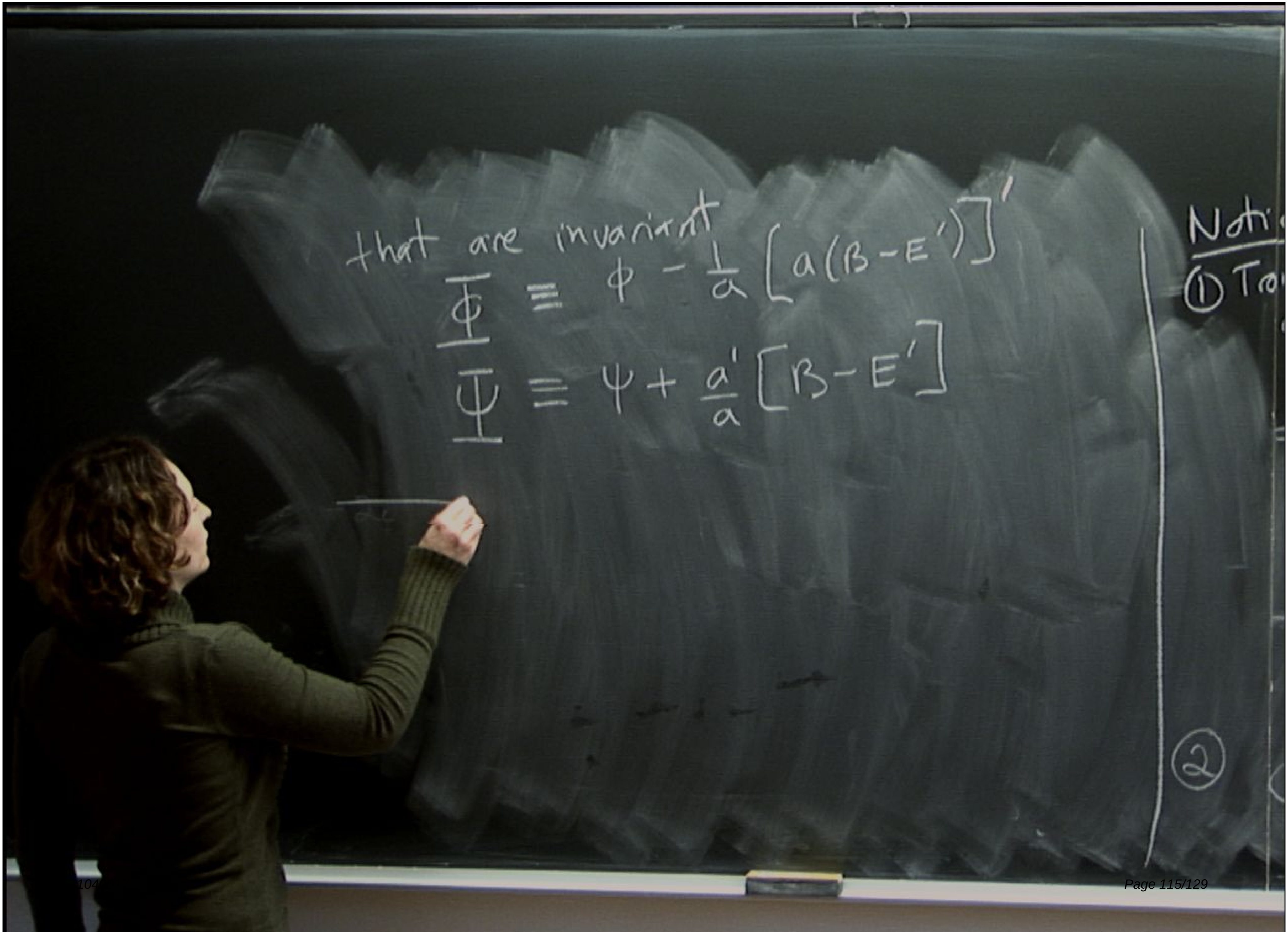
① Tr

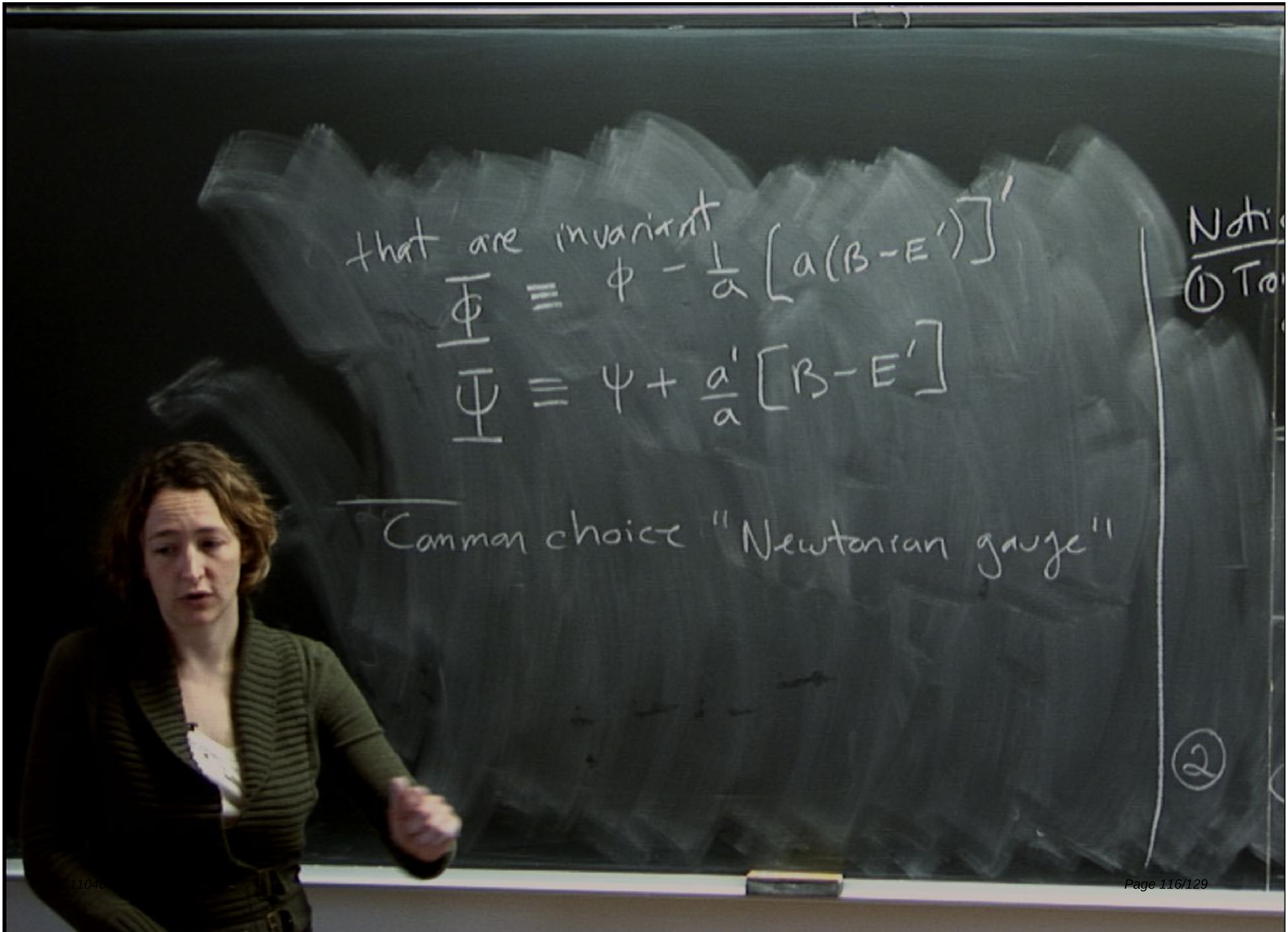
②


that are invariant
$\Phi \equiv \phi - \frac{1}{a}$
$\Psi \equiv \psi$
①
②

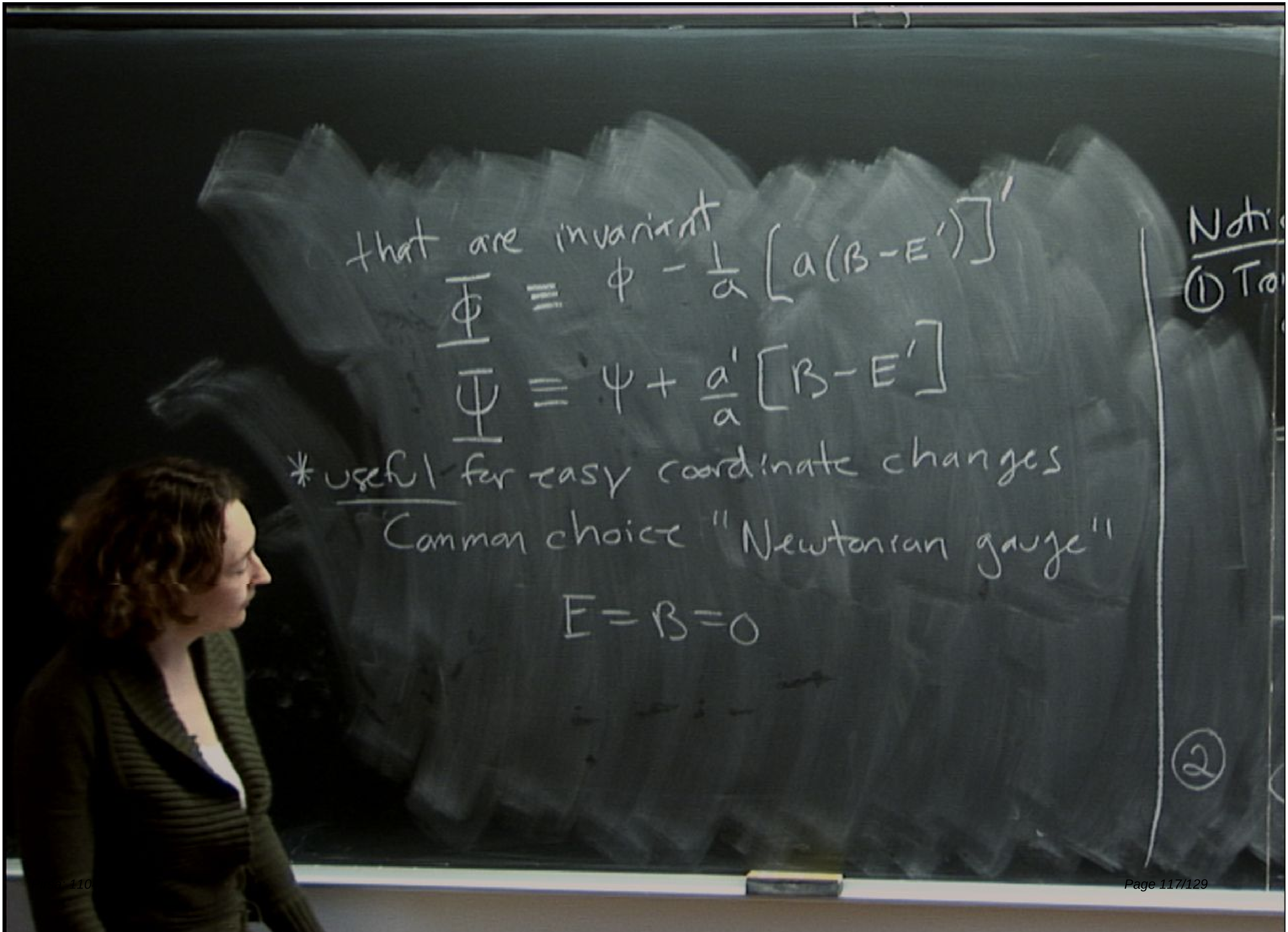


that are invariant
$\Phi \equiv \phi - \frac{1}{a}\left[a(B-E')\right]'$
$\Psi \equiv \psi + \frac{a'}{a}\left[B-E'\right]$
Noti
① Tr
②


that are invariant
$\Phi \equiv \phi - \frac{1}{a}\left[a(B-E')\right]'$
$\Psi \equiv \psi + \frac{a'}{a}\left[B-E'\right]$



that are invariant
$\Phi \equiv \phi - \frac{1}{a}\left[a(B-E')\right]'$
$\Psi \equiv \psi + \frac{a'}{a}\left[B-E'\right]$
Common choice "Newtonian gauge"


that are invariant
$\Phi \equiv \phi - \frac{1}{a}\left[a(B-E')\right]'$
$\Psi \equiv \psi + \frac{a'}{a}\left[B-E'\right]$
* useful for easy coordinate changes
Common choice "Newtonian gauge"
$E=B=0$

$$a^2\left[-(1+2\phi)\,d\eta^2 - 2B_{,i}\,dx^i d\eta + \left[(1-2\psi)\delta_{ij} - 2E_{,ij}\right]dx^i dx^j\right]$$

dinate transformation

infinitesimal

$$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$$

tion (spatial) $\quad \xi^i = \xi^i_\perp + \partial^i \xi$

scalar

$$\partial_i(\xi^i_\perp) = 0$$

Similarly

$$\tilde{\psi} = \psi + \frac{a'}{a}\xi^0$$

$$\tilde{B} = B + \xi' - \xi^0$$

$$\tilde{E} = E + \xi$$

$$\tilde{\phi} = \phi - \frac{1}{a}(a\xi^0)'$$

that are invariant

$$\Phi \equiv \phi - \frac{1}{a}\left[a(B-E')\right]'$$

$$\Psi \equiv \psi + \frac{a'}{a}\left[B-E'\right]$$

* useful for easy coordinate changes

Common choice "Newtonian gauge"

$$E = B = 0$$

→ Careful! Eg "Synchronous gauge"

Noti

① Tr

②

$$a^2\Big[-(1+2\phi)d\eta^2 - 2B_{,i}\, dx^i d\eta$$
$$+\big[(1-2\psi)\delta_{ij} - 2E_{,ij}\big]dx^i dx^j\Big]$$

...dinate transformation

infinitesimal

$$x^\mu \longrightarrow \tilde{x}^\mu = x^\mu + \xi^\mu(x,t)$$

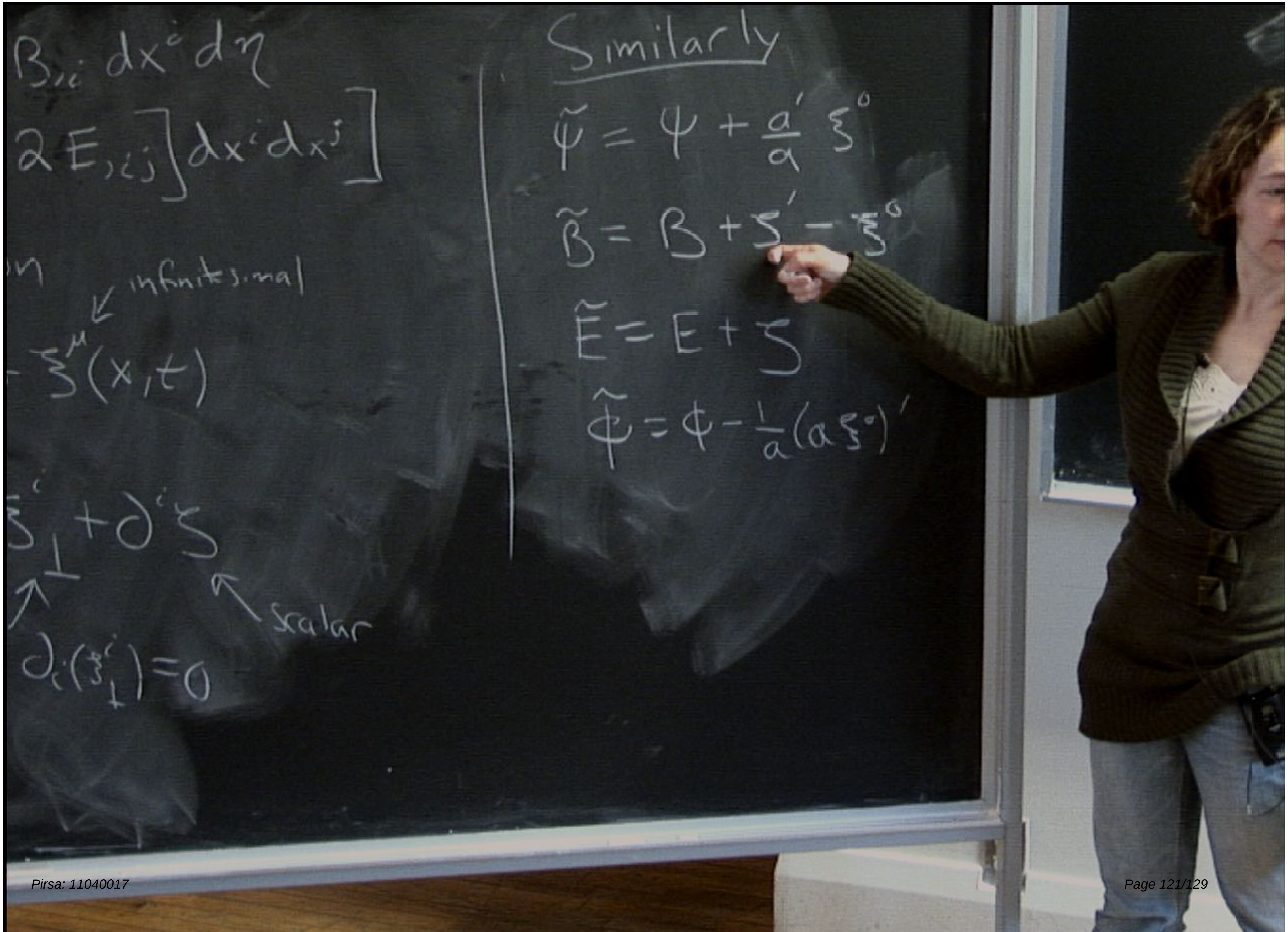
...ition (spatial) $\quad \xi^i = \xi^i_\perp + \partial^i \xi$

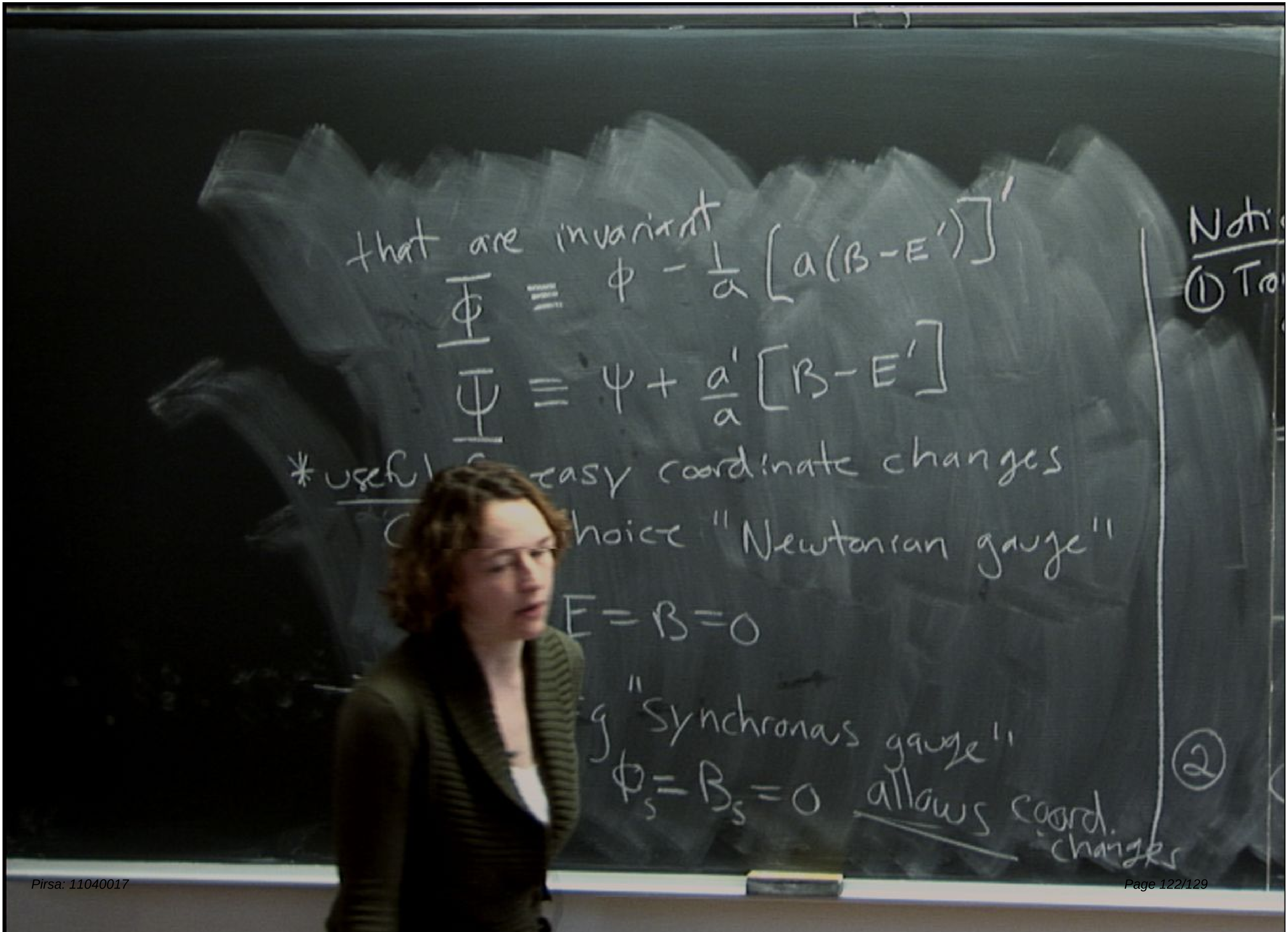
$\partial_i(\xi^i_\perp) = 0$

scalar

Similarly

$$\tilde{\psi} = \psi + \frac{a'}{a}\xi^0$$
$$\tilde{B} = B + \xi' - \xi^0$$
$$\tilde{E} = E + \xi$$
$$\tilde{\phi} = \phi - \frac{1}{a}(a\xi^0)'$$


$B_{,i}\, dx^i d\eta$
$2E_{,ij}]\, dx^i dx^j]$
infinitesimal
$\xi^\mu(x,t)$
$\xi^i_\perp + \partial^i \xi$
scalar
$\partial_i(\xi^i_\perp) = 0$
Similarly
$\tilde\psi = \psi + \frac{a'}{a}\xi^0$
$\tilde B = B + \xi' - \xi^0$
$\tilde E = E + \xi$
$\tilde\phi = \phi - \frac{1}{a}(a\xi^0)'$


that are invariant
$\Phi \equiv \phi - \frac{1}{a}\left[a(B-E')\right]'$
$\Psi \equiv \psi + \frac{a'}{a}\left[B-E'\right]$
* useful
easy coordinate changes
choice "Newtonian gauge"
$E = B = 0$
"Synchronous gauge"
$\phi_s = B_s = 0$ allows coord. changes
Noti
① Tr
②

ce

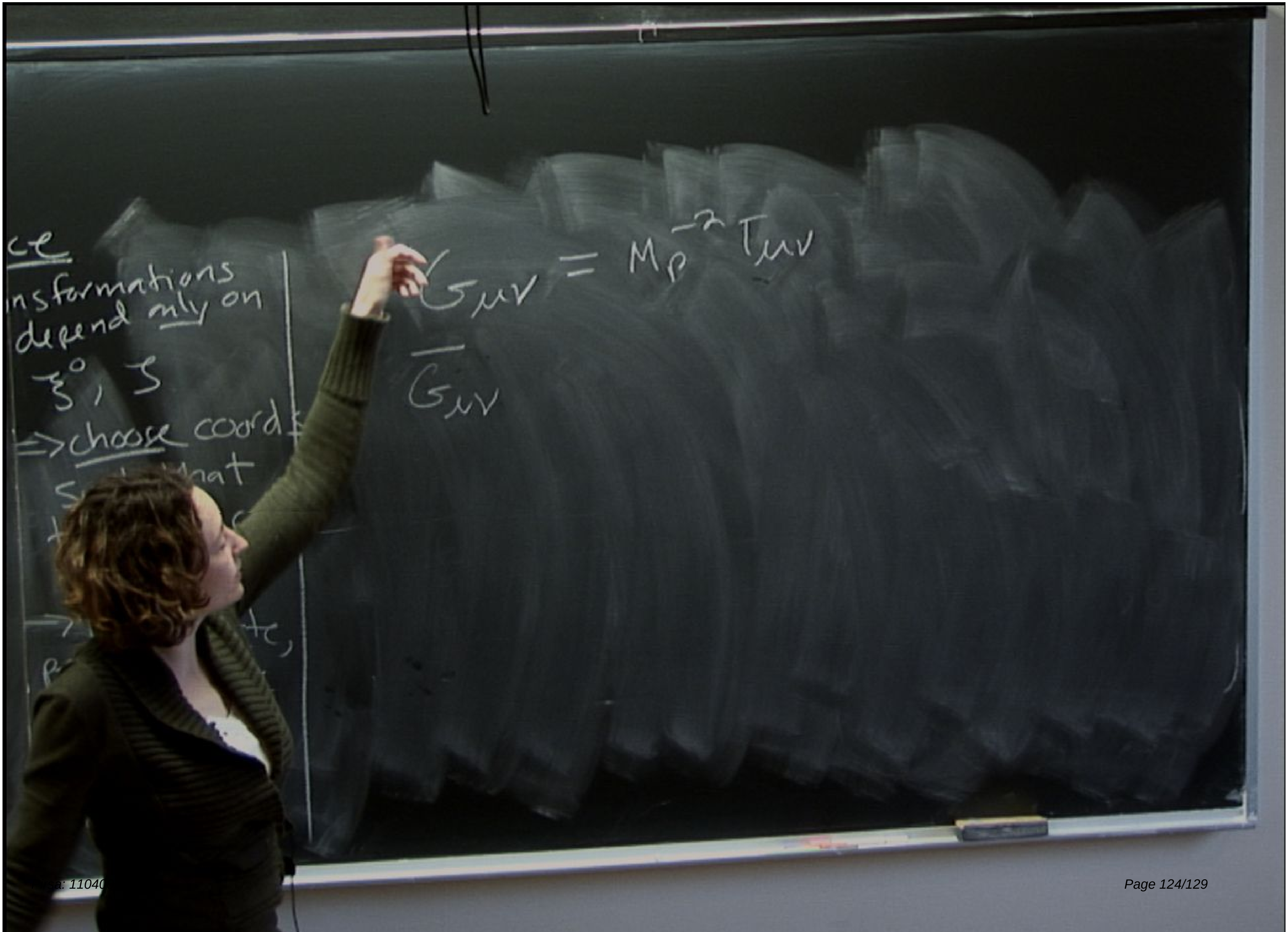
nsformations
depend only on
ξ^0, ξ

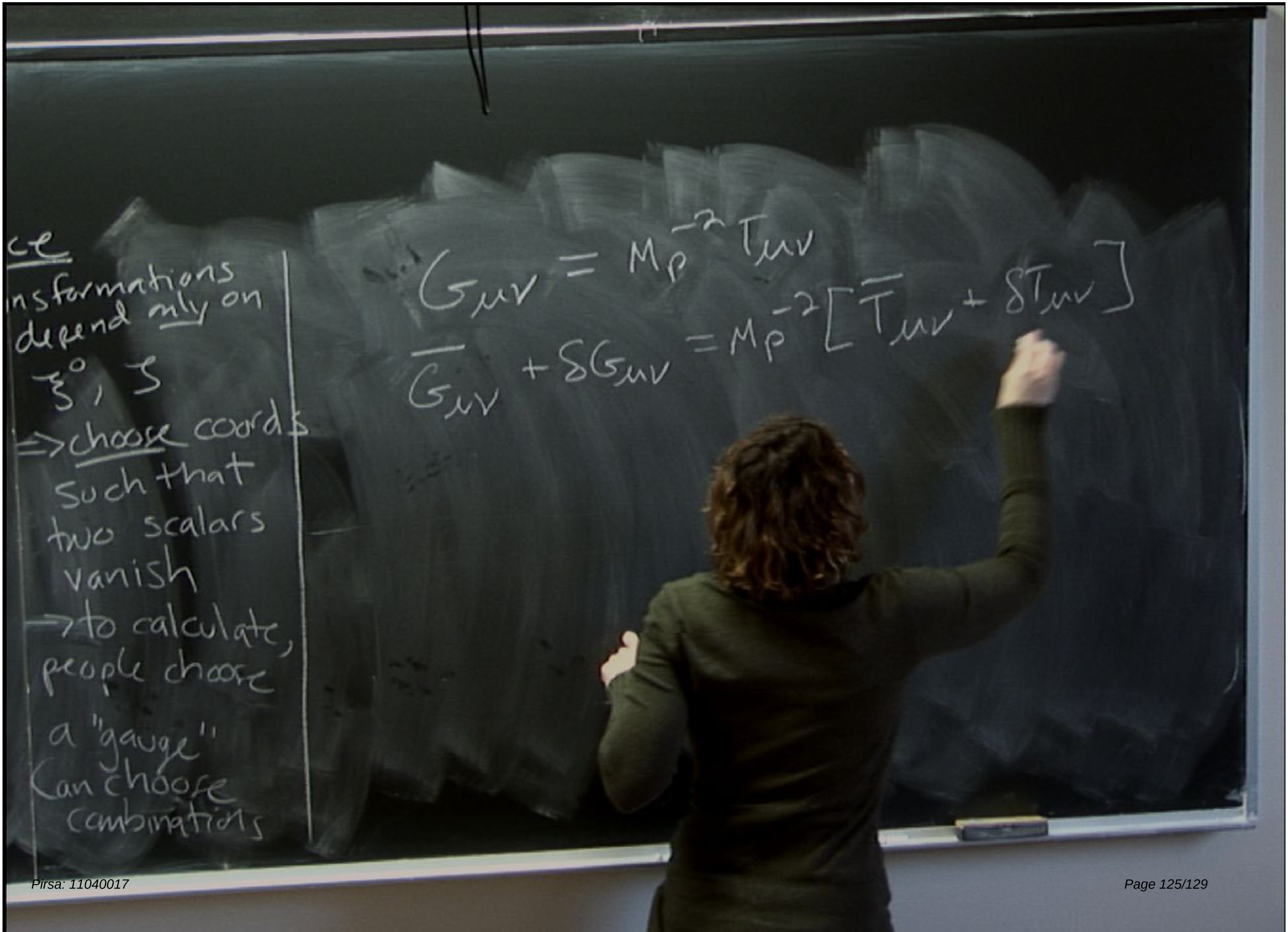
$\Rightarrow$ choose coords
such that
two scalars
vanish

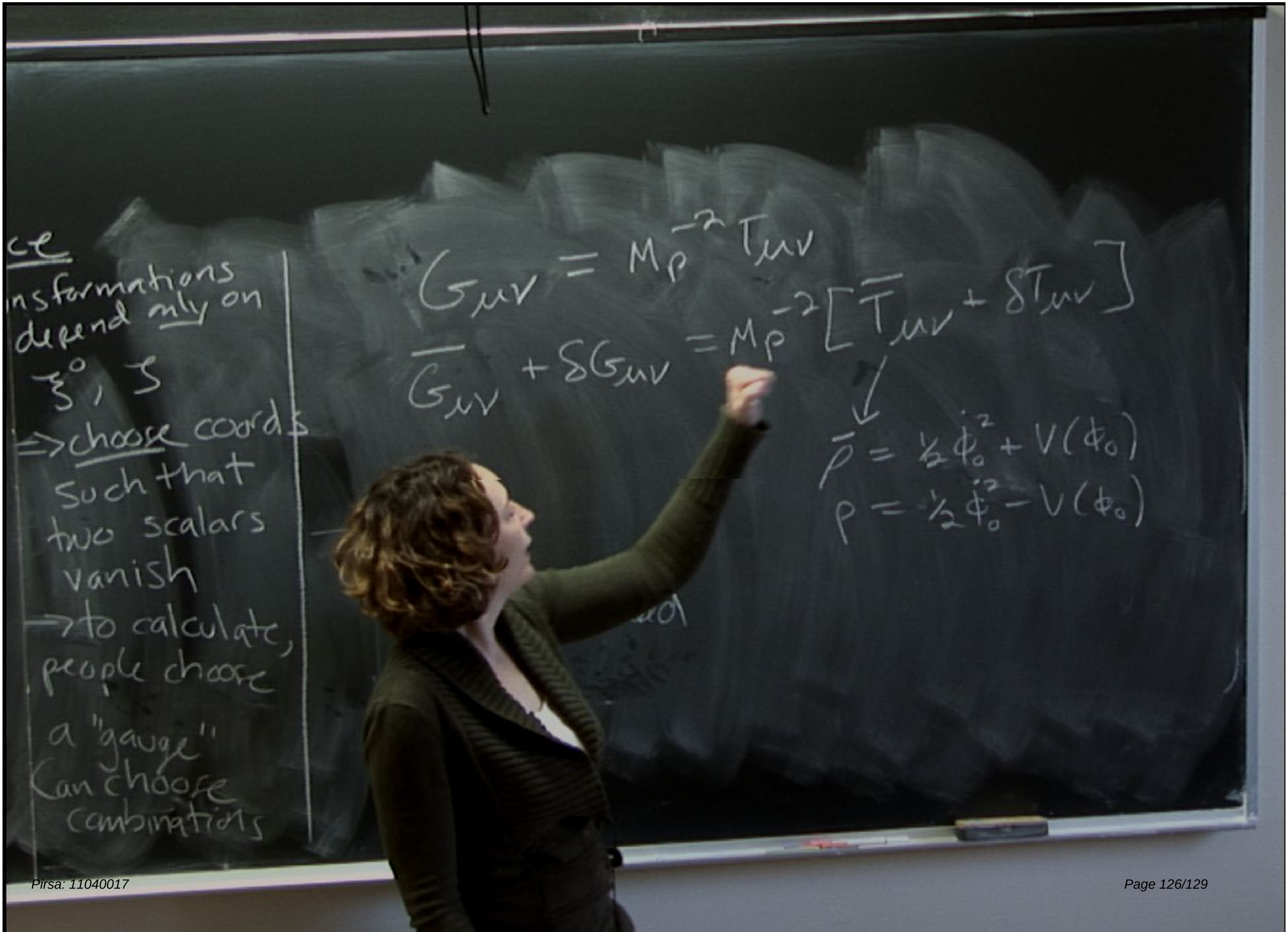
$\rightarrow$ to calculate,
people choose
a "gauge"

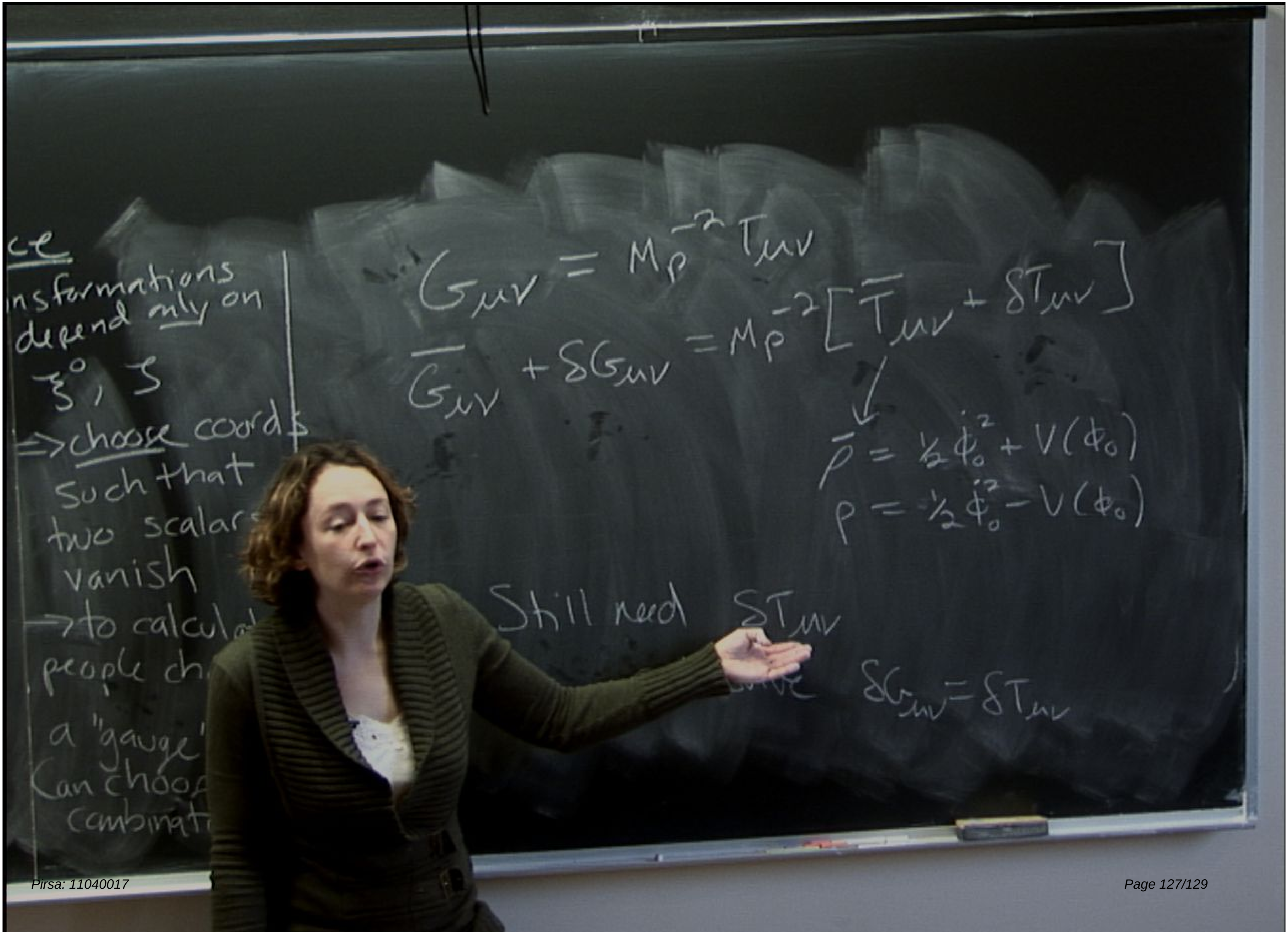
Can choose
combinations

$$G_{\mu\nu} = M_p^{-2} T_{\mu\nu}$$


ce
insformations
depend only on
ξ°, ξ
⇒choose coord
that
$G_{\mu\nu} = M_p^{-2} T_{\mu\nu}$
$\bar{G}_{\mu\nu}$


ce
nsformations
depend only on
ξ^0, ξ
⇒ choose coords
such that
two scalars
vanish
→ to calculate,
people choose
a "gauge"
Can choose
combinations
$G_{\mu\nu} = M_p^{-2} T_{\mu\nu}$
$\bar{G}_{\mu\nu} + \delta G_{\mu\nu} = M_p^{-2} [\bar{T}_{\mu\nu} + \delta T_{\mu\nu}]$


ce
nsformations
depend only on
ξ^0, ξ
⇒ choose coords
such that
two scalars
vanish
→ to calculate,
people choose
a "gauge"
Can choose
combinations
$G_{\mu\nu} = M_p^{-2} T_{\mu\nu}$
$\bar{G}_{\mu\nu} + \delta G_{\mu\nu} = M_p^{-2}[\bar{T}_{\mu\nu} + \delta T_{\mu\nu}]$
$\bar{\rho} = \frac{1}{2}\dot{\phi}_0^2 + V(\phi_0)$
$p = \frac{1}{2}\dot{\phi}_0^2 - V(\phi_0)$


ce
nsformations
depend only on
ξ^0, ξ
⇒ choose coords
such that
two scalar
vanish
→ to calcul
people ch
a "gauge"
Can choo
combinat
$G_{\mu\nu} = M_p^{-2} T_{\mu\nu}$
$\bar{G}_{\mu\nu} + \delta G_{\mu\nu} = M_p^{-2}[\bar{T}_{\mu\nu} + \delta T_{\mu\nu}]$
$\bar{\rho} = \frac{1}{2}\dot{\phi}_0^2 + V(\phi_0)$
$p = \frac{1}{2}\dot{\phi}_0^2 - V(\phi_0)$
Still need $\delta T_{\mu\nu}$
$\delta G_{\mu\nu} = \delta T_{\mu\nu}$

ce

insformations
depend only on
ξ^0, ξ

$\Rightarrow$ choose coords
such that
two scalars
vanish

$\rightarrow$ to calculate,
people choose
a "gauge"
Can choose
combinations

$$G_{\mu\nu} = M_p^{-2} T_{\mu\nu}$$

$$\bar{G}_{\mu\nu} + \delta G_{\mu\nu} = M_p^{-2}\left[\bar{T}_{\mu\nu} + \delta T_{\mu\nu}\right]$$

$$\bar{\rho} = \tfrac{1}{2}\dot{\phi}_0^2 + V(\phi_0)$$

$$p = \tfrac{1}{2}\dot{\phi}_0^2 - V(\phi_0)$$

Still need $\delta T_{\mu\nu}$

and solve $\delta G_{\mu\nu} = \delta T_{\mu\nu}$

ce

nsformations
depend only on
ξ^0, ξ
$\Rightarrow$ choose coords
such that
two scalars
vanish
$\Rightarrow$ to calculate,
people choose
a "gauge"
can choose
combinations

$$G_{\mu\nu} = M_p^{-2} T_{\mu\nu}$$

$$\bar{G}_{\mu\nu} + \delta G_{\mu\nu} = M_p^{-2}\left[\bar{T}_{\mu\nu} + \delta T_{\mu\nu}\right]$$

$$\bar{\rho} = \tfrac{1}{2}\dot{\phi}_0^2 + V(\phi_0)$$

$$p = \tfrac{1}{2}\dot{\phi}_0^2 - V(\phi_0)$$

Still need $\delta T_{\mu\nu}$

and solve $\delta G_{\mu\nu} = \delta T_{\mu\nu}$