Title: Surprising consequence of a positive cosmological constant

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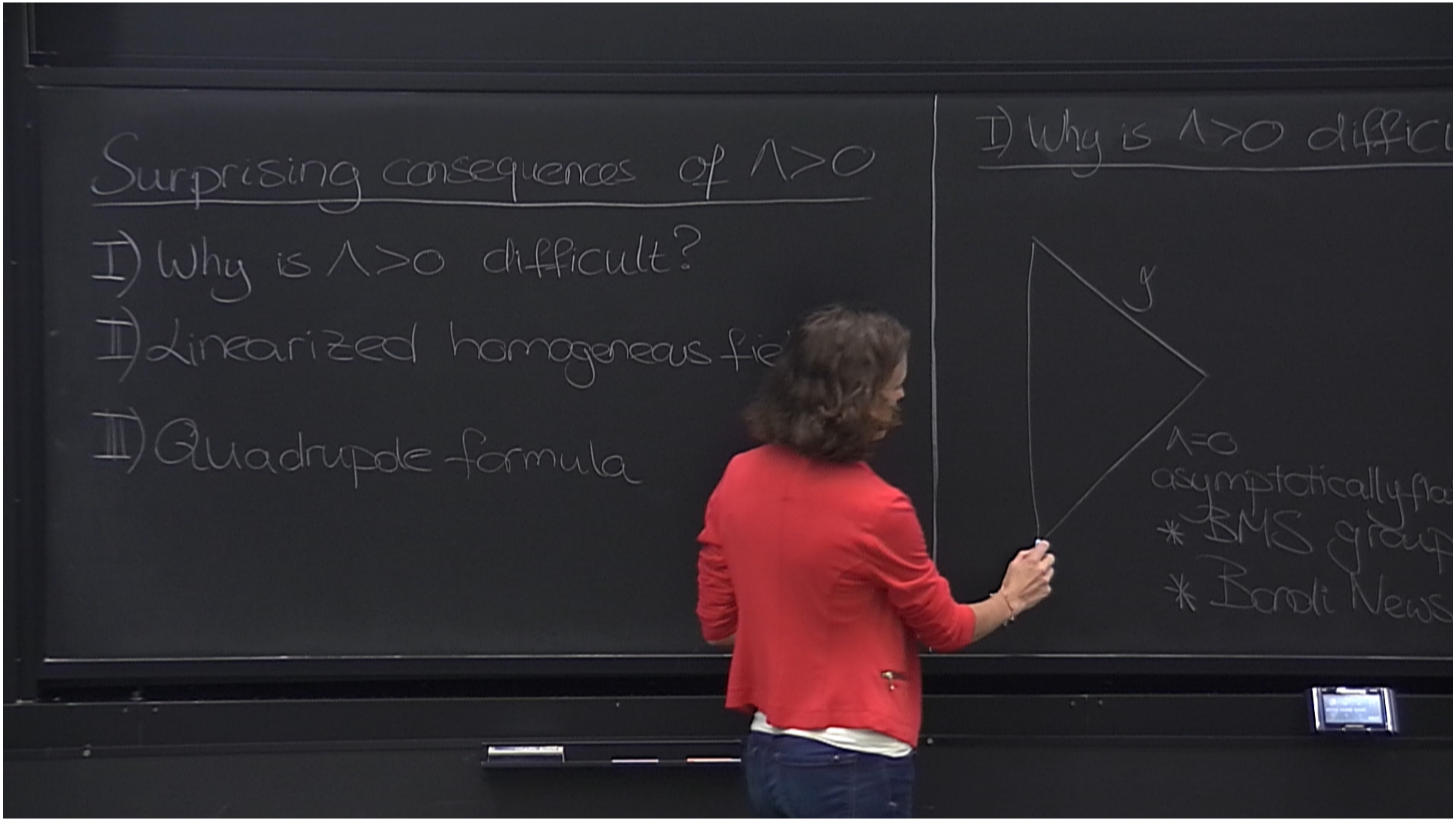
Abstract: <p>The study of isolated systems has been vastly successful in the context of vanishing cosmological constant, $\Lambda = 0$. However, there is no physically useful notion of asymptotics for the universe we inhabit with $\Lambda > 0$. The full non-linear framework is still under development, but some interesting results at the linearized level have been obtained. I will focus on the conceptual subtleties that arise at the linearized level and discuss the quadrupole formula for gravitational radiation.</p>


Surprising consequences of Λ>0
I) Why is Λ>0 difficult?
II) Linearized homogeneous fie
III) Quadrupole formula
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Λ=0
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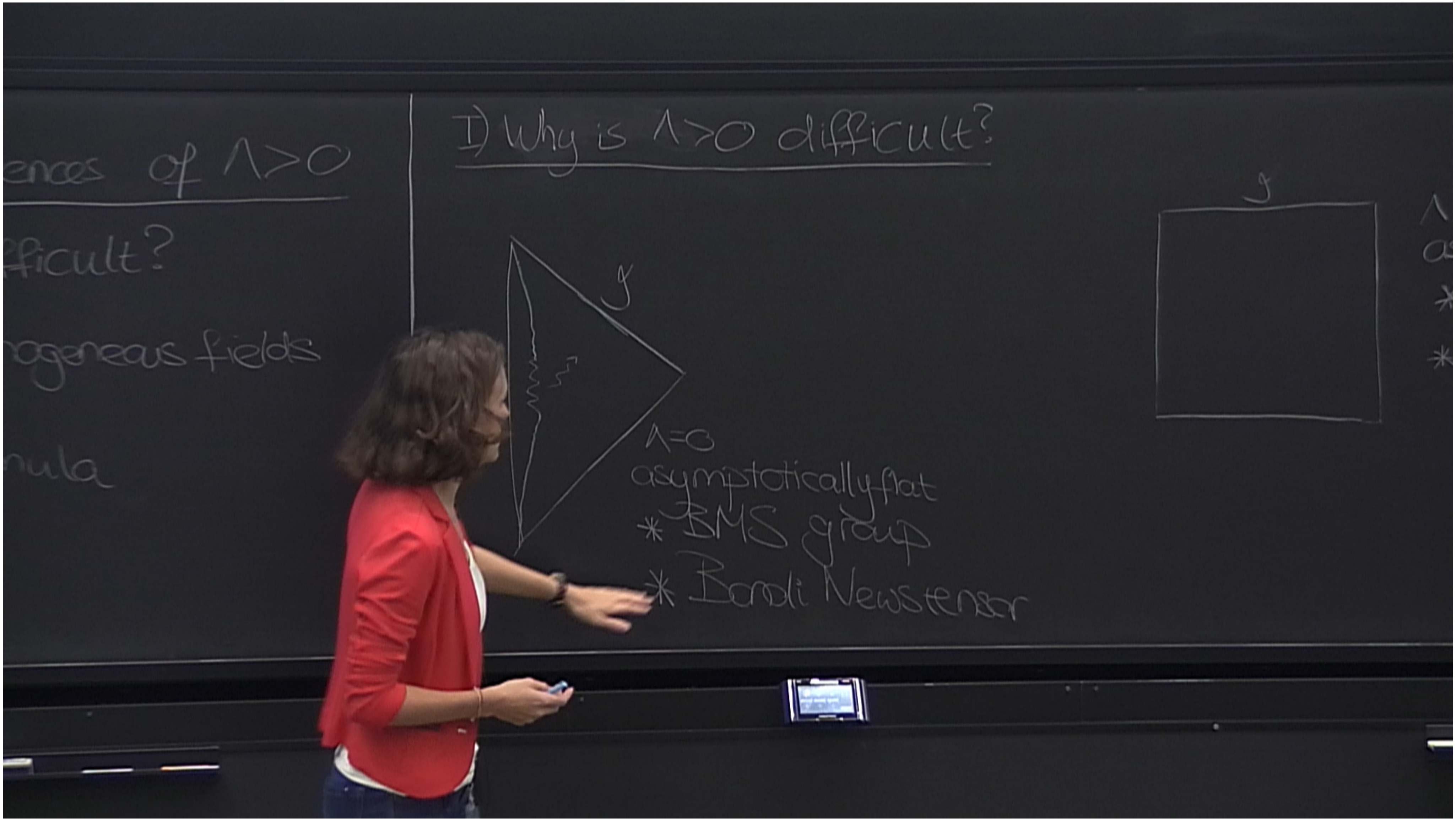
* BMS grou
* Bondi News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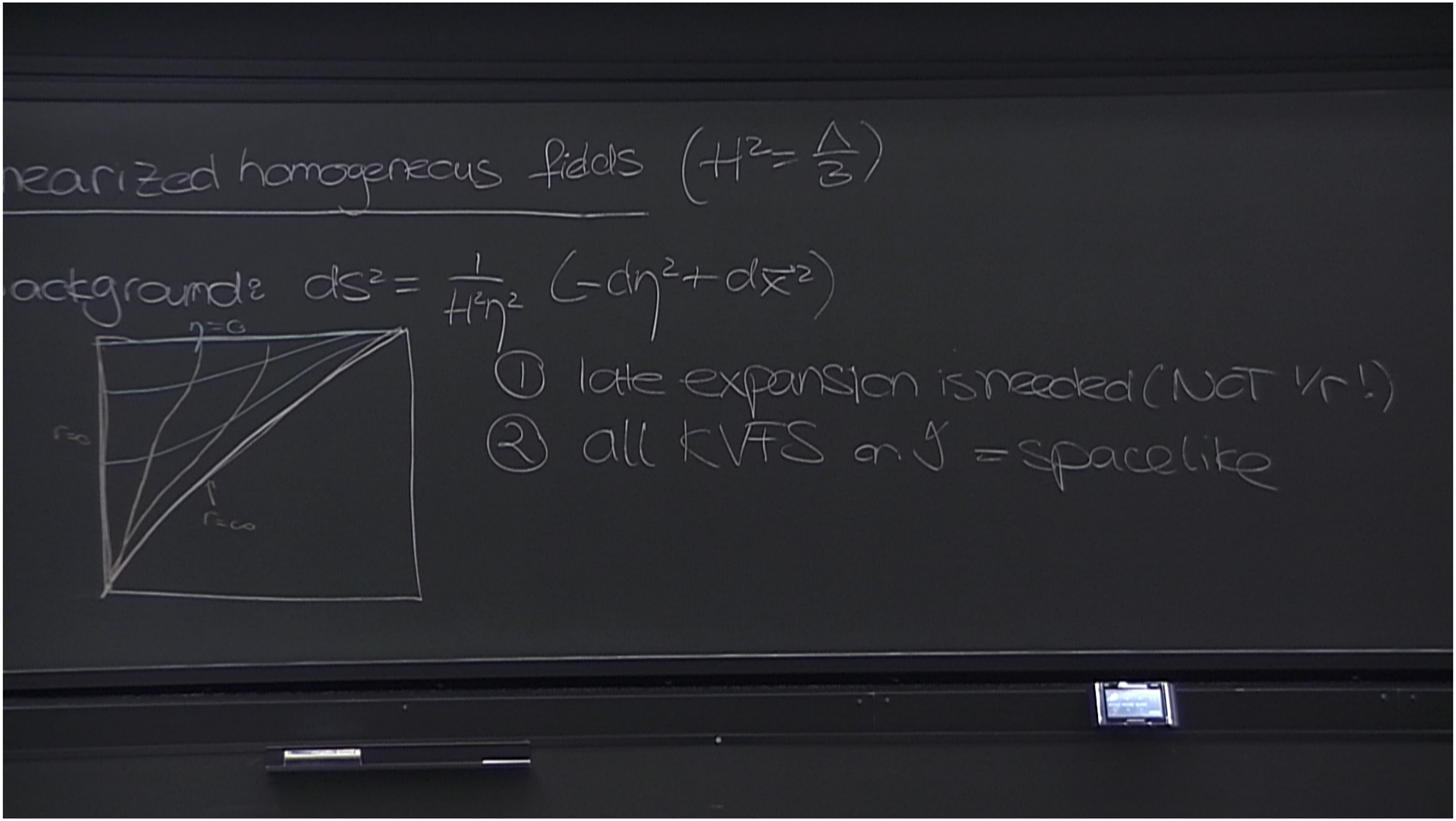
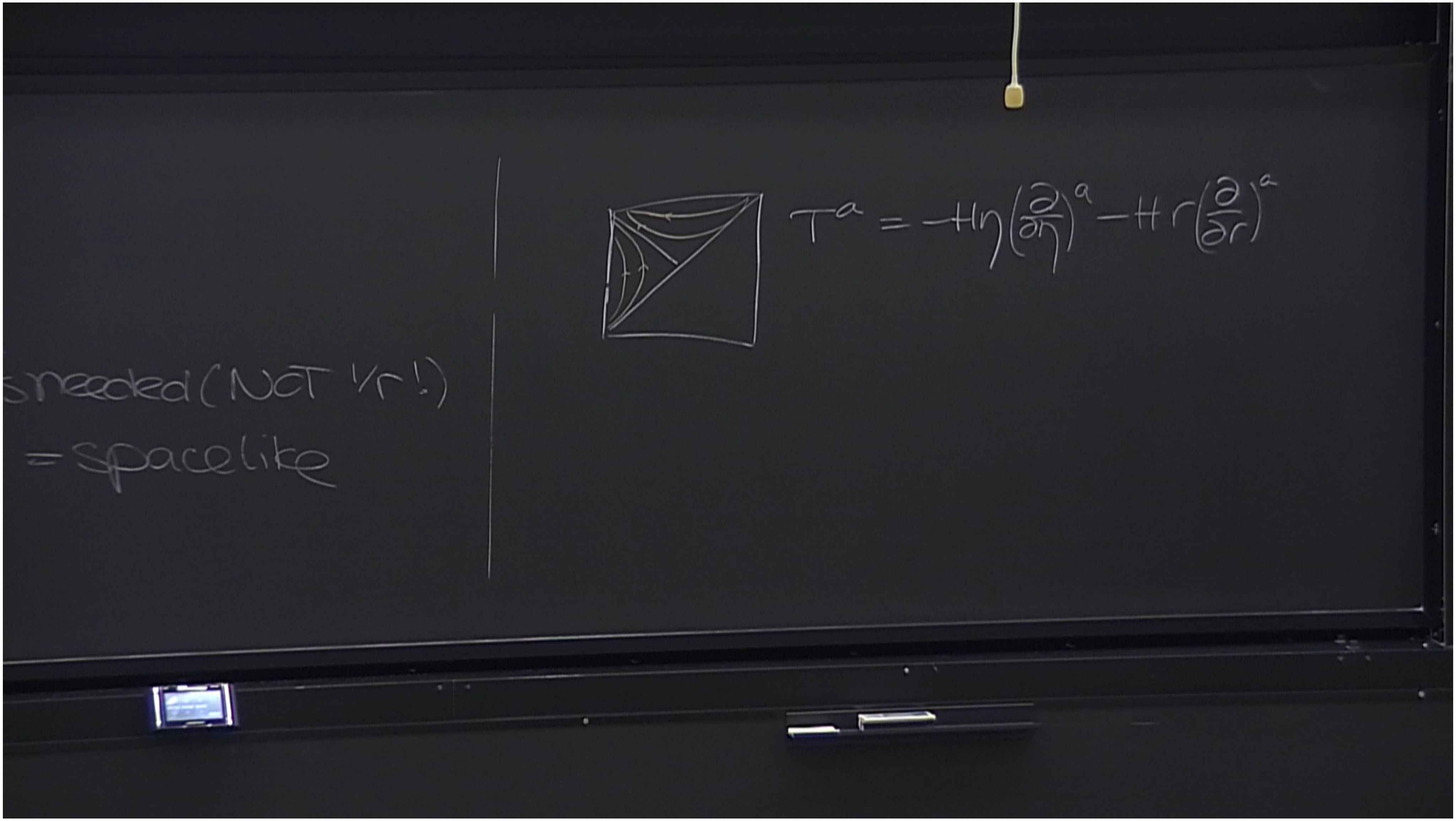
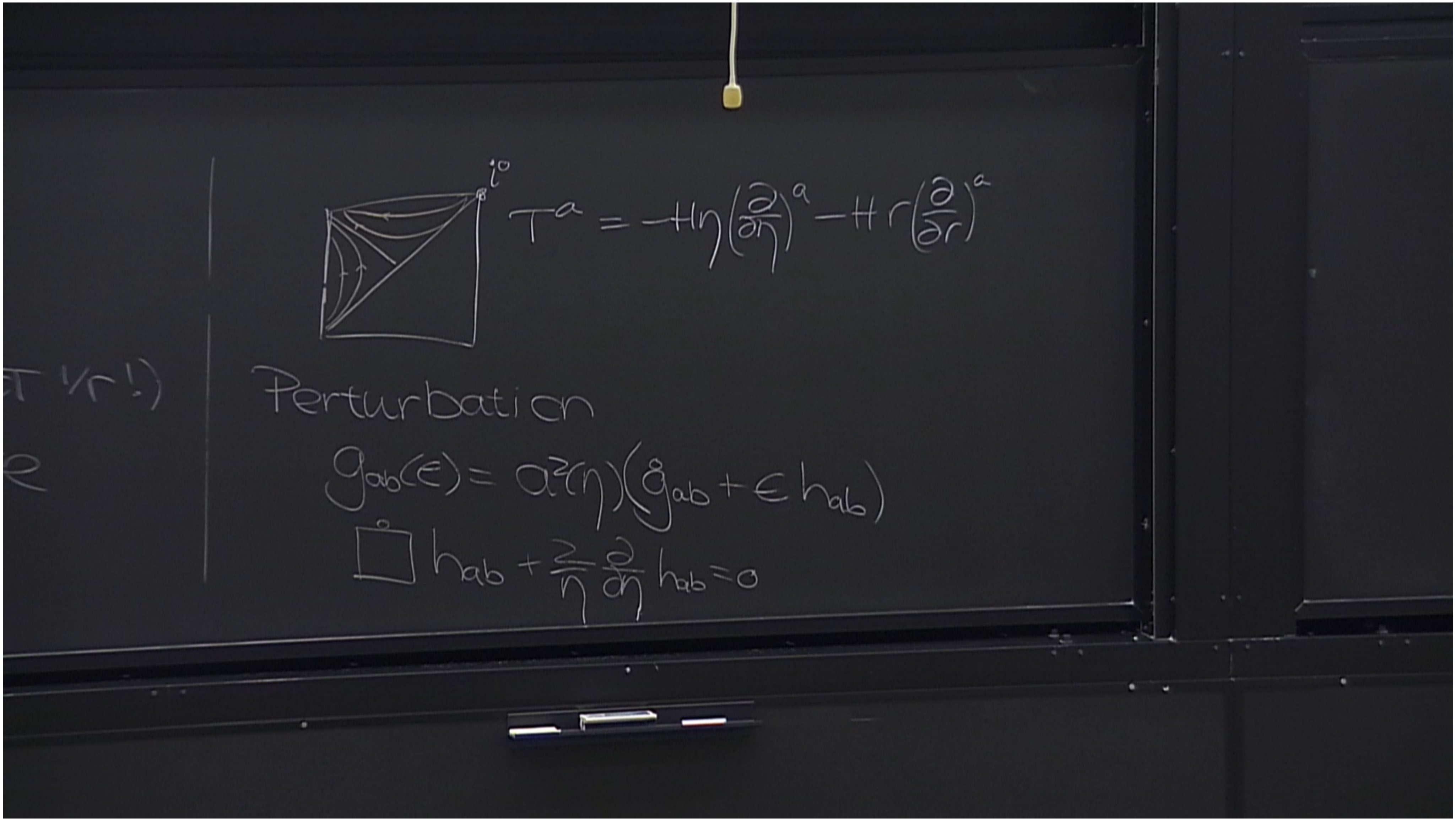

nearized homogeneous fields $(H^2 = \frac{\Lambda}{3})$
ackground: $ds^2 = \frac{1}{H^2\eta^2}(-d\eta^2 + d\vec{x}^2)$
$\eta=0$
$r=0$
$r=\infty$
① late expansion is needed (NOT 1/r!)
② all KVFS on $\mathcal{I}$ = spacelike


s needed (NOT 1/r!)
= spacelike
$T^a = -t\eta\left(\frac{\partial}{\partial\eta}\right)^a - t\,r\left(\frac{\partial}{\partial r}\right)^a$


i^0
$T^a = -t\eta\left(\frac{\partial}{\partial\eta}\right)^a - tr\left(\frac{\partial}{\partial r}\right)^a$
Perturbation
$g_{ab}(\epsilon) = a^2(\eta)\left(\mathring{g}_{ab} + \epsilon h_{ab}\right)$
$\mathring{\Box} h_{ab} + \frac{2}{\eta}\frac{\partial}{\partial\eta} h_{ab} = 0$

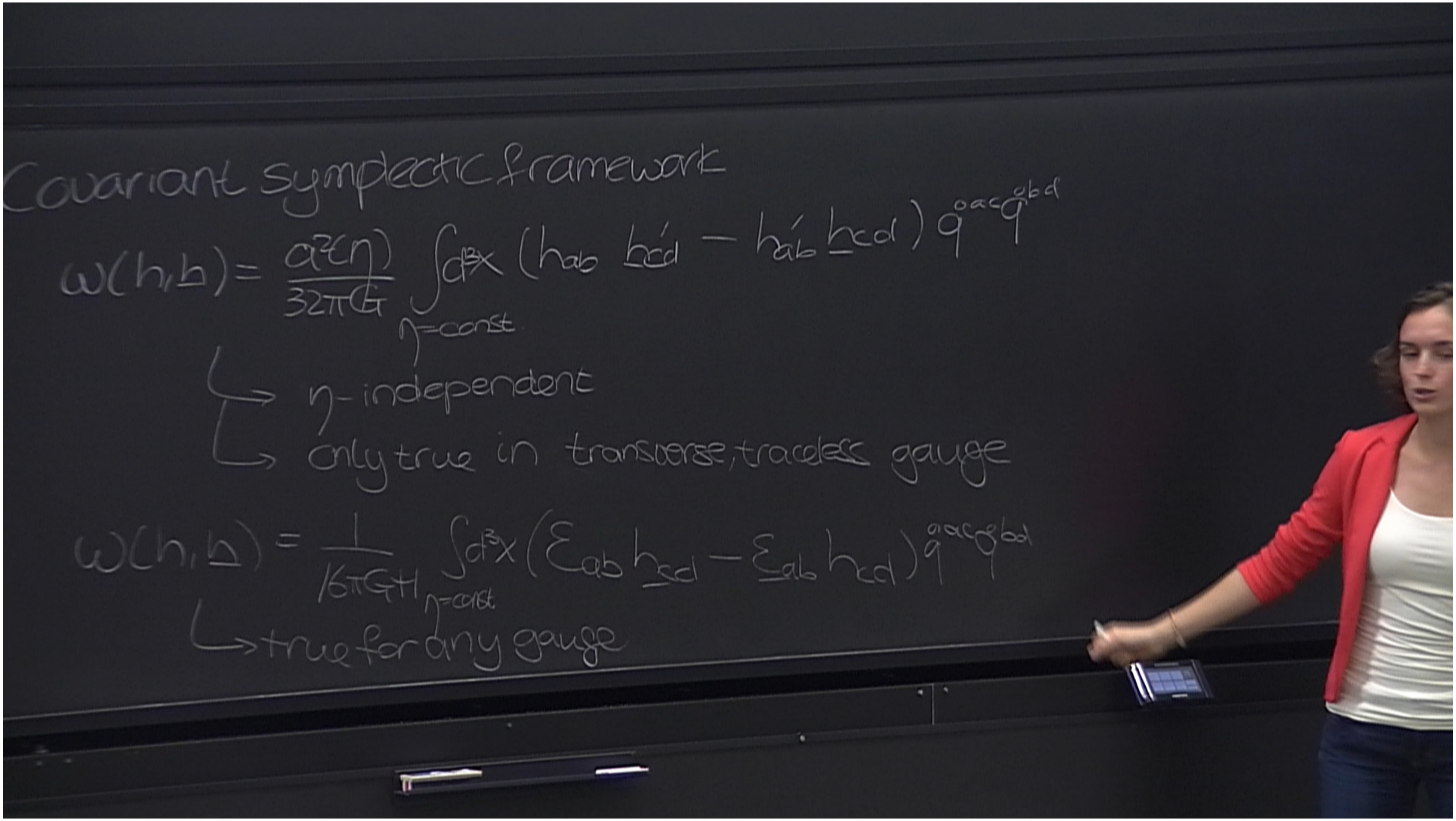
Covariant symplectic framework

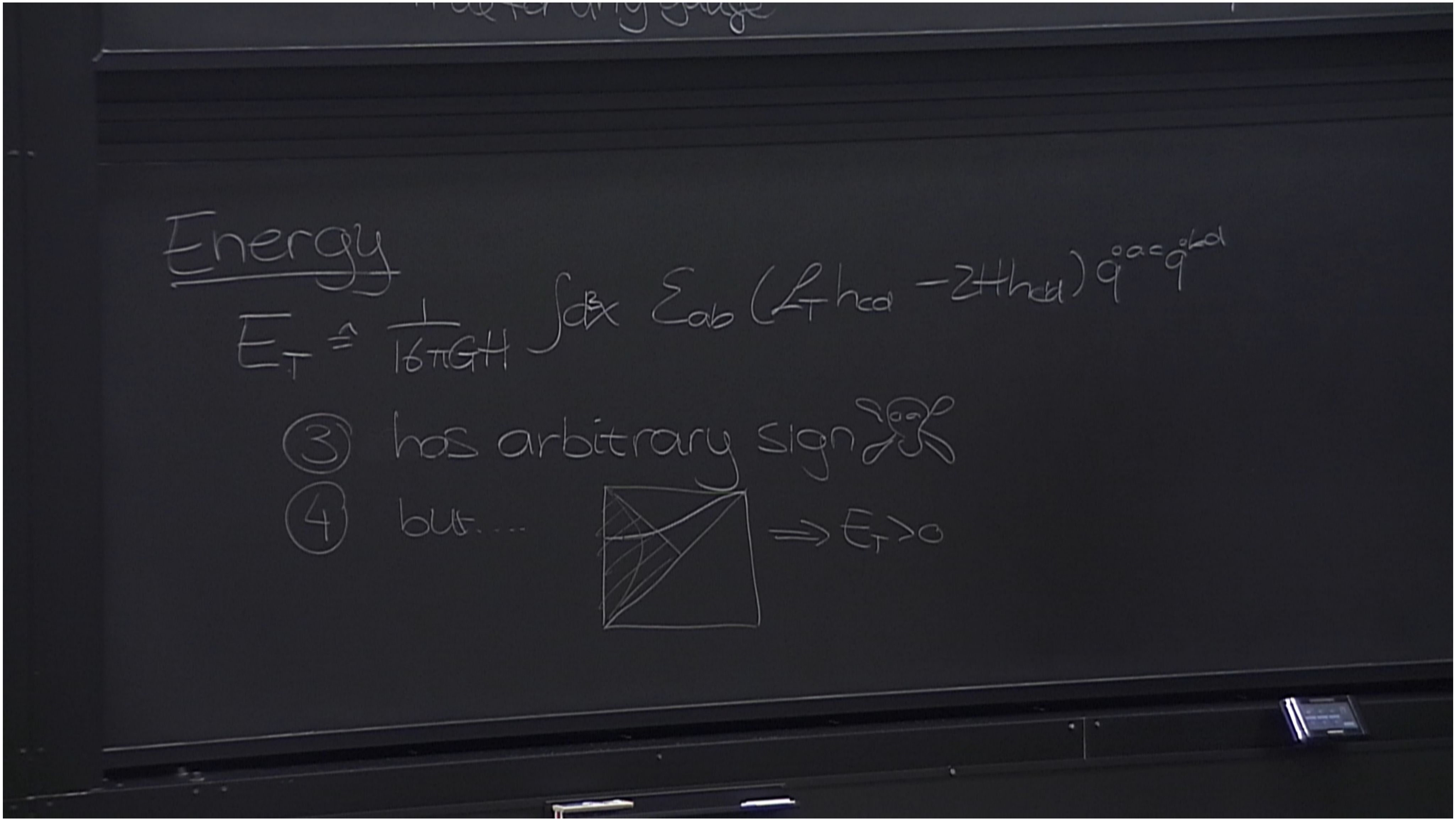
$$\omega(h,\underline{h}) = \frac{a^2(\eta)}{32\pi G}\int_{\eta=\text{const}} d^3x\,\left(h_{ab}\,\underline{h}'_{cd} - h'_{ab}\,\underline{h}_{cd}\right) g^{ac} g^{bd}$$

↳ η-independent

↳ only true in transverse, traceless gauge

$$\omega(h,\underline{h}) = \frac{1}{16\pi G H}\int d^3x\,\left(\mathcal{E}_{ab}\,\underline{h}_{cd} - \underline{\mathcal{E}}_{ab}\,h_{cd}\right) g^{ac} g^{bd}$$


Covariant symplectic framework
$\omega(h,\underline{h}) = \frac{a^2(\eta)}{32\pi G}\int_{\eta=\text{const}} d^3x\,(h_{ab}\,\underline{h}'_{cd} - h'_{ab}\,\underline{h}_{cd})\,g^{ac}g^{bd}$
↳ η- independent
↳ only true in transverse, traceless gauge
$\omega(h,\underline{h}) = \frac{1}{16\pi G H}\int_{\eta=\text{const}} d^3x\,(\mathcal{E}_{ab}\,\underline{h}_{cd} - \underline{\mathcal{E}}_{ab}\,h_{cd})\,g^{ac}g^{bd}$
↳ true for any gauge


Energy
$E_T \hat{=} \frac{1}{16\pi G H} \int d^3x \, \mathcal{E}_{ab} (\mathcal{L}_T h_{cd} - 2H h_{cd}) \, q^{ac} q^{bd}$
3 has arbitrary sign
4 but....
$\Rightarrow E_T > 0$

$\ldots_{cd} - 2H h_{cd}) \mathring{g}^{ac} \mathring{g}^{bd}$

$E_T > 0$

(5) Limit $\Lambda \to 0$ is subte!

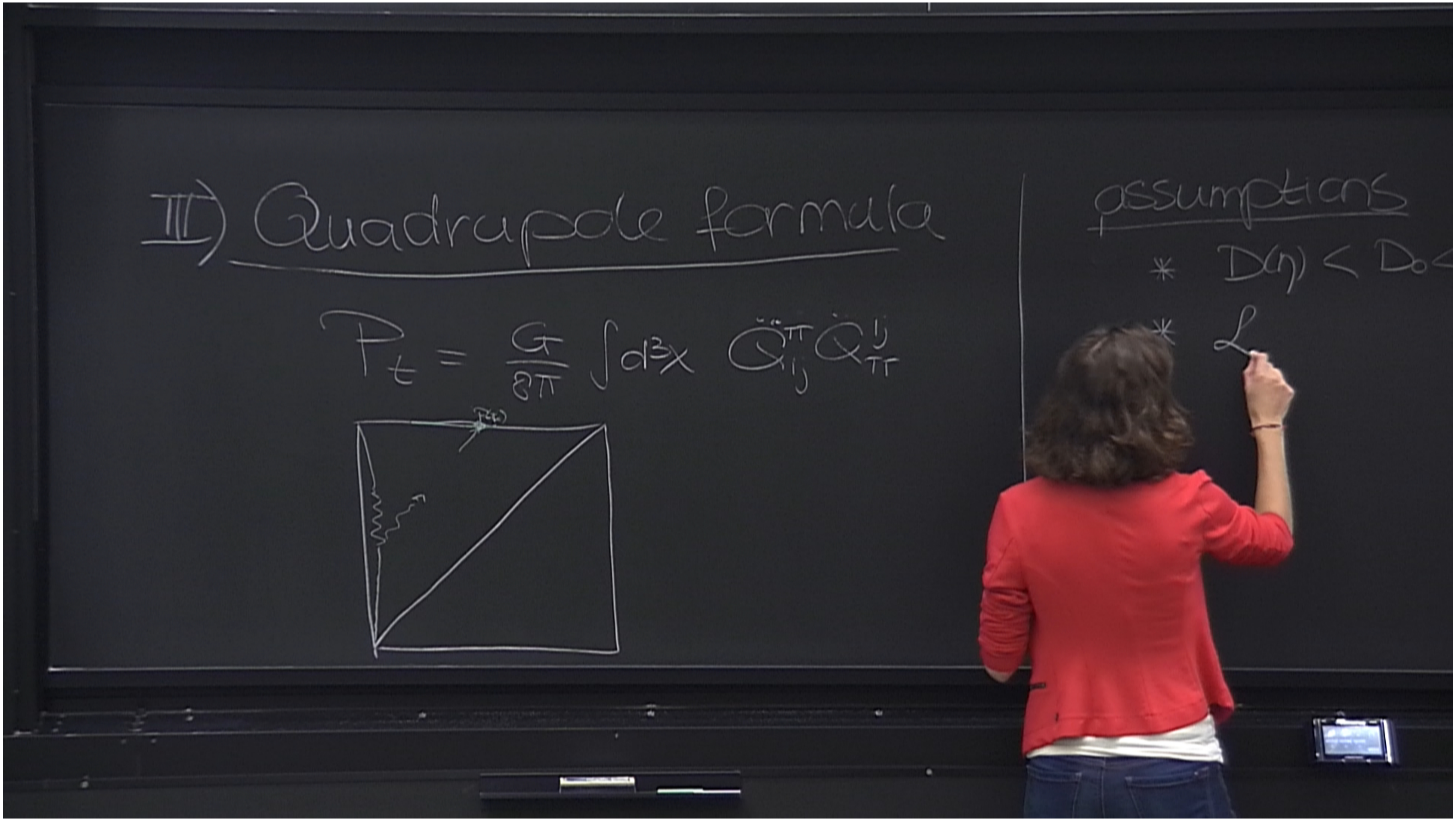
Use structure provided $(t, \vec{x})$:

$$ds^2 = -dt^2 + e^{2Ht} d\vec{x}^2$$

$$E_T \longrightarrow \mathring{E}_t$$

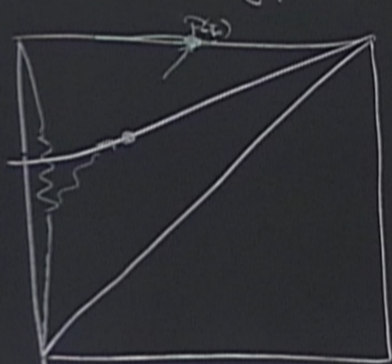
III) Quadrupole formula

$$P_t = \frac{G}{8\pi} \int d^3x \; \dddot{Q}^{TT}_{ij} \, \dddot{Q}^{ij}_{TT}$$


III) Quadrupole formula
$P_t = \frac{G}{8\pi} \int d^3x \, \dddot{Q}^{TT}_{ij} \dddot{Q}^{ij}_{TT}$
assumptions
* D(η) < D₀<
* L

III) Quadrupole formula

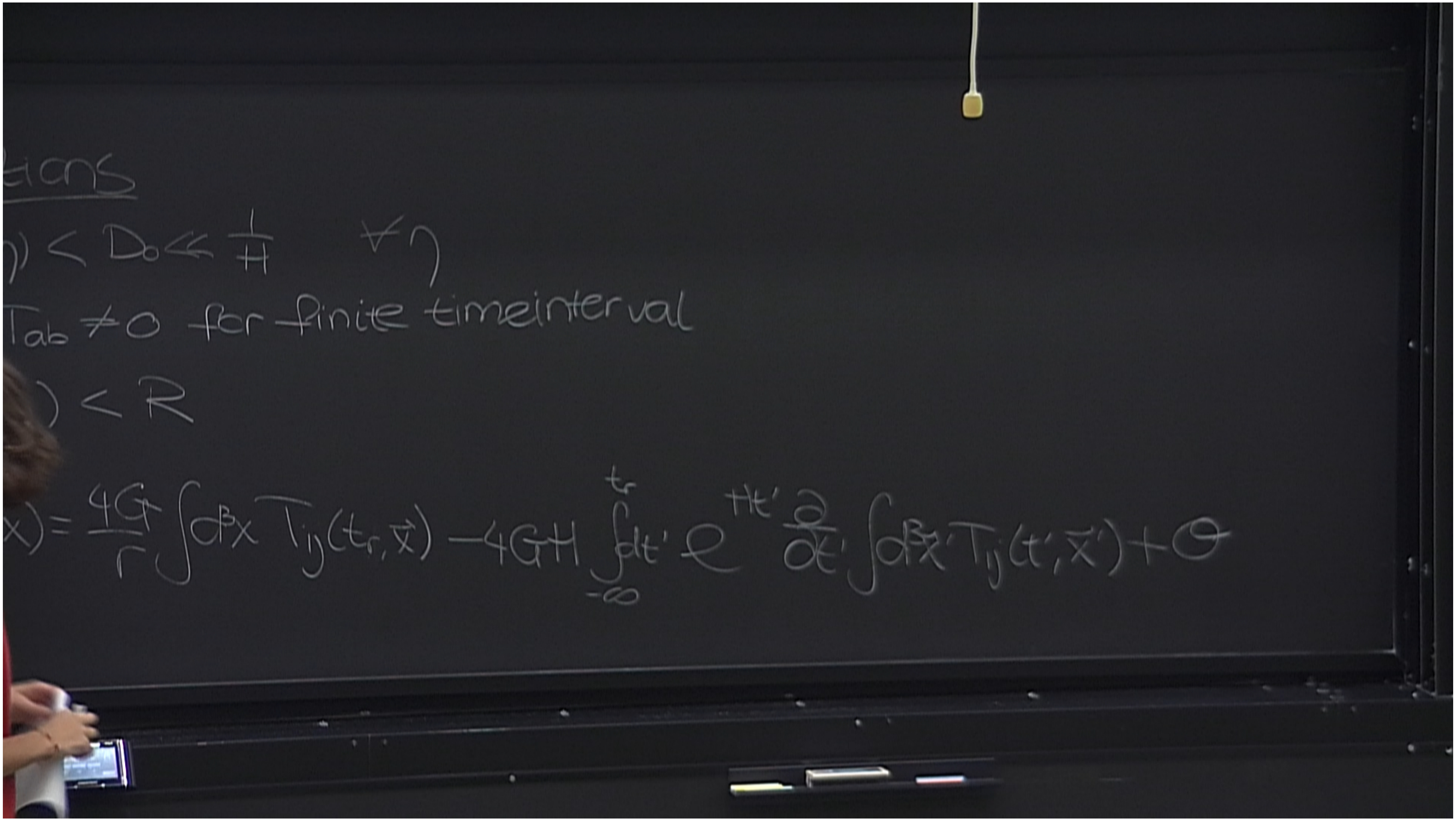
$$P_t = \frac{G}{8\pi}\int d^3x \, \dddot{Q}^{TT}_{ij}\,\dddot{Q}^{ij}_{TT}$$

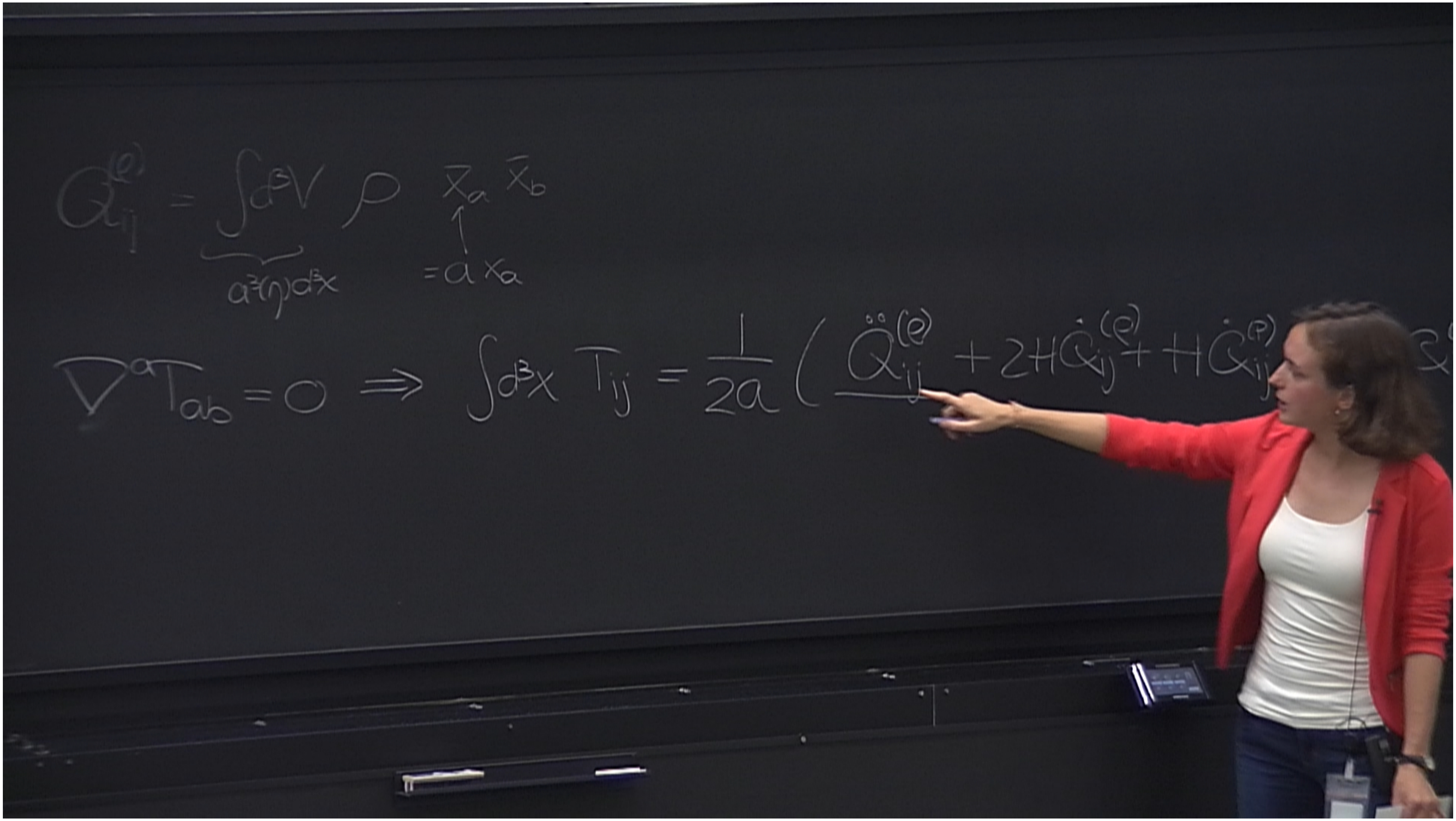


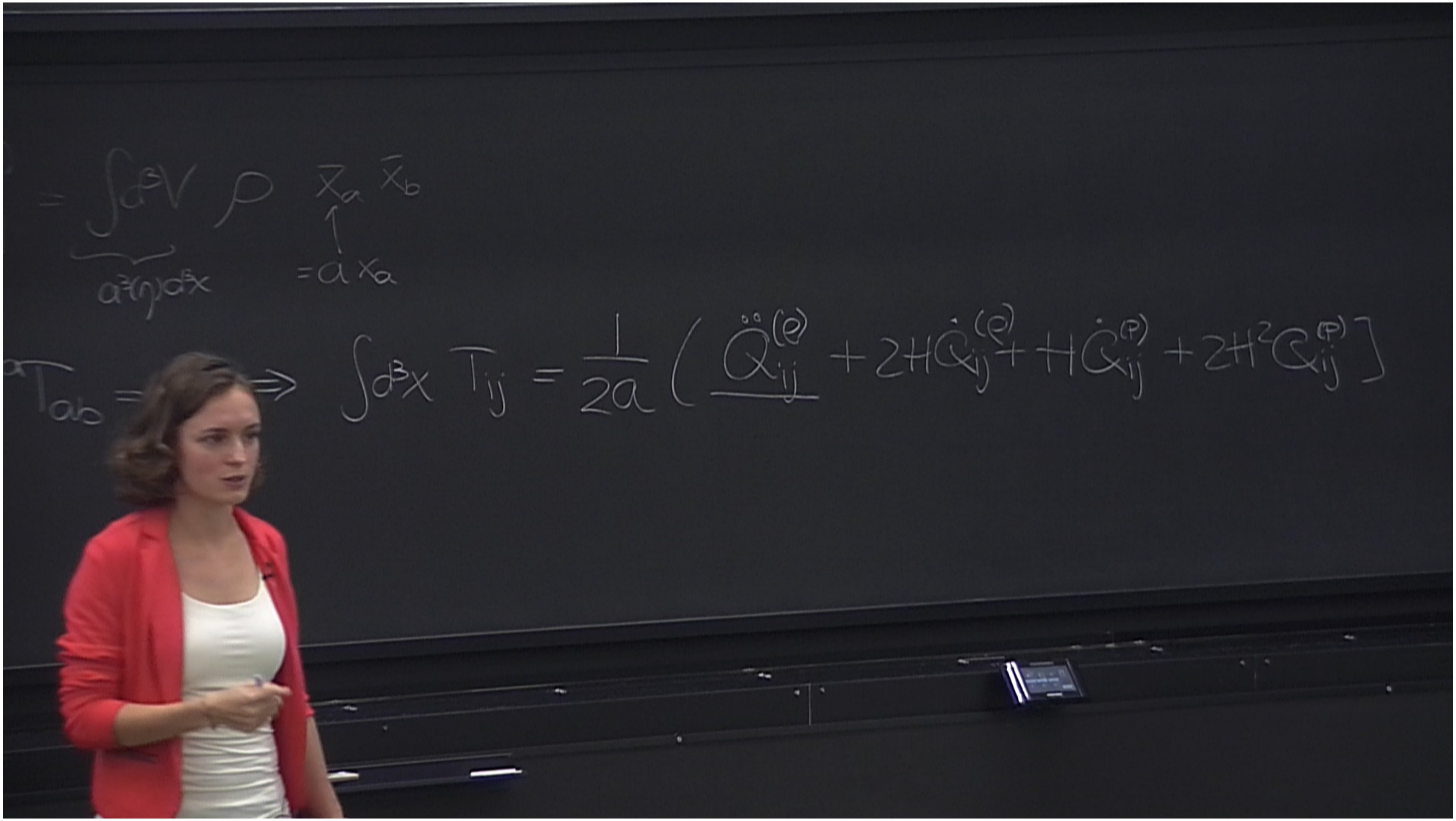
assumptions

* $D(\eta) < D_0 \ll \frac{1}{H}$
* $\mathcal{L}_T T_{ab} \neq 0$ for fin
* $D(\eta) < R$

$\Rightarrow \underline{h}_{ij}(t,x) = \frac{4G}{r}\int d^3x \, T_{ij}(t$

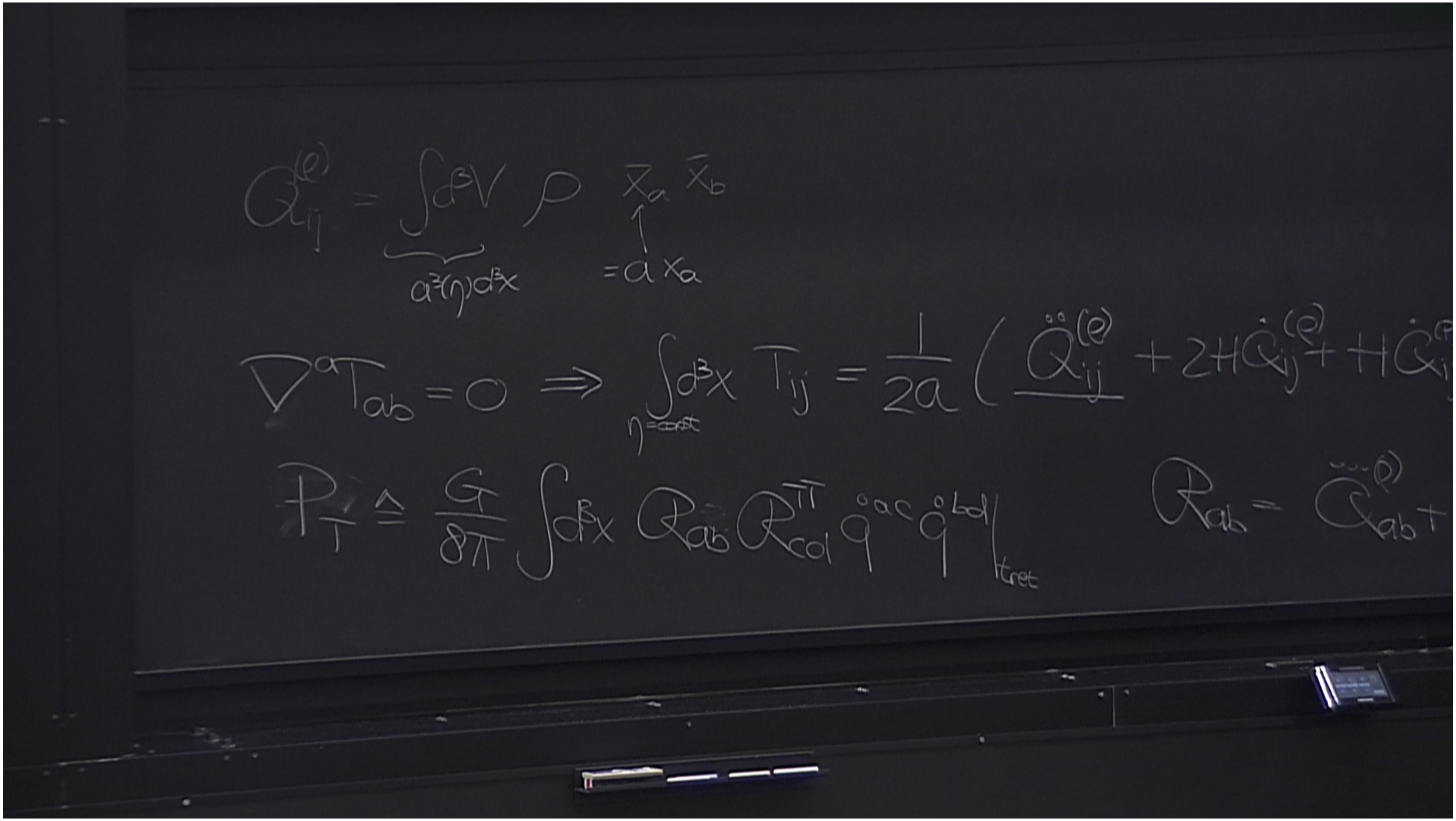

tions
$) < D_0 \ll \frac{1}{H} \quad \forall \eta$
$T_{ab} \neq 0$ for finite timeinterval
$) < R$
$x) = \frac{4G}{r}\int d^3x\, T_{ij}(t_r,\vec{x}) - 4GH\int_{-\infty}^{t_r} dt'\, e^{Ht'} \frac{\partial}{\partial t'}\int d^3x'\, T_{ij}(t',\vec{x}') + \Theta$


$Q_{ij}^{(e)} = \underbrace{\int d^3V}_{a^3(\eta)d^3x} \rho \, \bar{x}_a \bar{x}_b$
$\bar{x}_a = a x_a$
$\nabla^a T_{ab} = 0 \Rightarrow \int d^3x \, T_{ij} = \frac{1}{2a} \left(\ddot{Q}_{ij}^{(e)} + 2H\dot{Q}_{ij}^{(e)} + H\dot{Q}_{ij}^{(p)}\right.$


= ∫d³V ρ x̄a x̄b
a³(η)d³x
= a xa
Tab =
⟹ ∫d³x Tij = 1/2a (Q̈ij(e) + 2HQ̇ij(e) + HQ̇ij(p) + 2H²Qij(p)]

$$\Big[\underline{\ddot{Q}_{ij}^{(e)}} + 2H\dot{Q}_{ij}^{(e)} + H\dot{Q}_{ij}^{(p)} + 2H^2 Q_{ij}^{(p)} \Big]$$

$$R_{ab} = \dddot{Q}_{ab}^{(p)} + 3H\ddot{Q}_{ab}^{(p)} + 2H^2\dot{Q}_{ab}^{(p)} + H\ddot{Q}_{ab}^{(p)} + 3H^2\dot{Q}^{(p)} + 2H^3 Q_{ab}^{(p)}$$



$Q^{(e)}_{ij} = \underbrace{\int d^3V}_{a^3(\eta)\,d^3x} \rho \; \bar{x}_a \bar{x}_b$
$\bar{x}_a = a\, x_a$
$\nabla^a T_{ab} = 0 \Longrightarrow \int_{\eta=\mathrm{const}} d^3x \; T_{ij} = \frac{1}{2a}\Big(\underline{\ddot{Q}^{(e)}_{ij}} + 2H\dot{Q}^{(e)}_{ij} + H\dot{Q}_{ij}$
$P_T \triangleq \frac{G}{8\pi} \int d^3x \; \mathcal{Q}_{ab} \mathcal{Q}^{TT}_{cd} \, \mathring{q}^{ac} \mathring{q}^{bd} \Big|_{t_{ret}}$
$\mathcal{Q}_{ab} = \dddot{Q}^{(\rho)}_{ab} +$