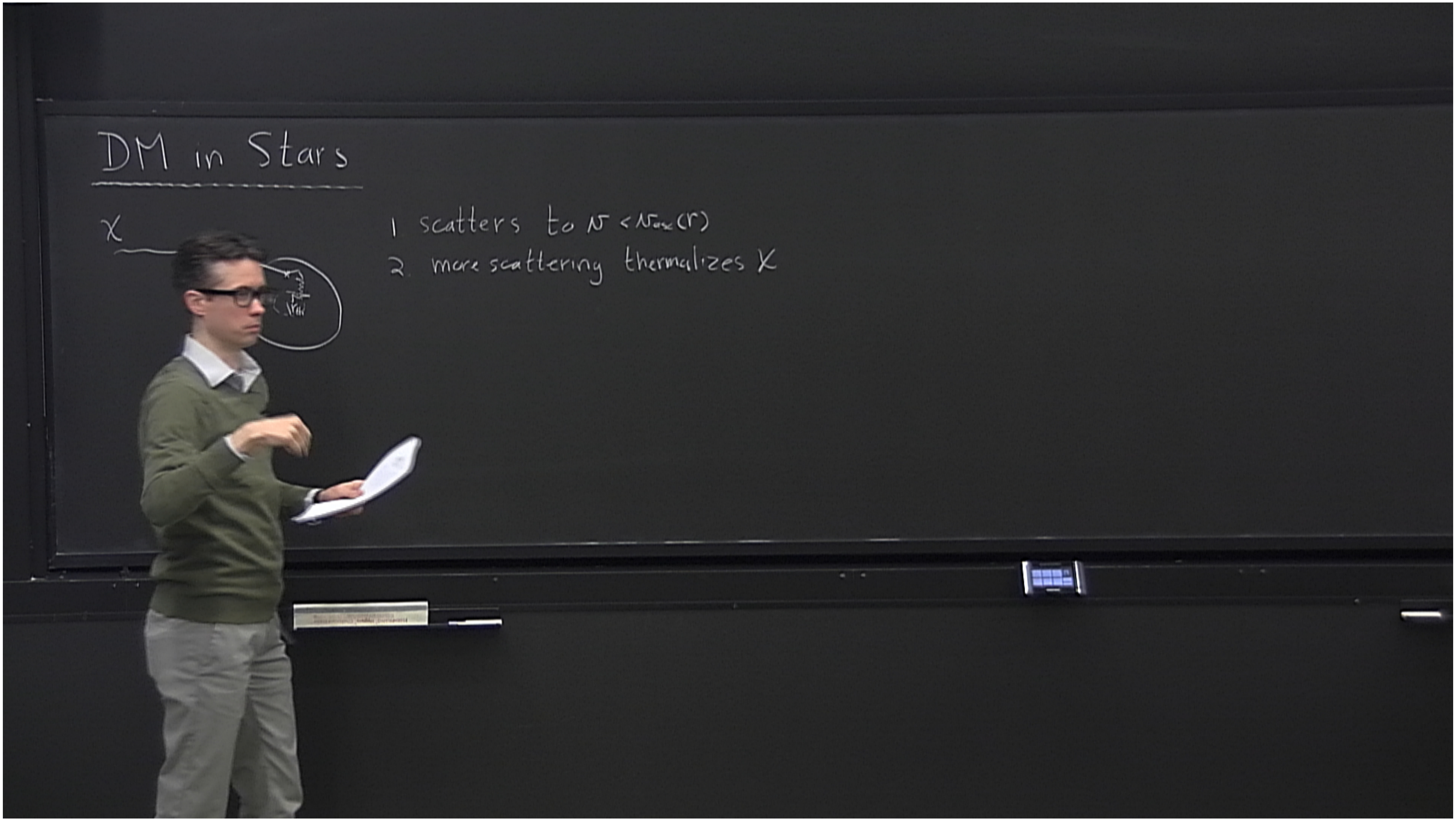
Title: 12/13 PSI - Explorations in Particle Theory Lecture 13

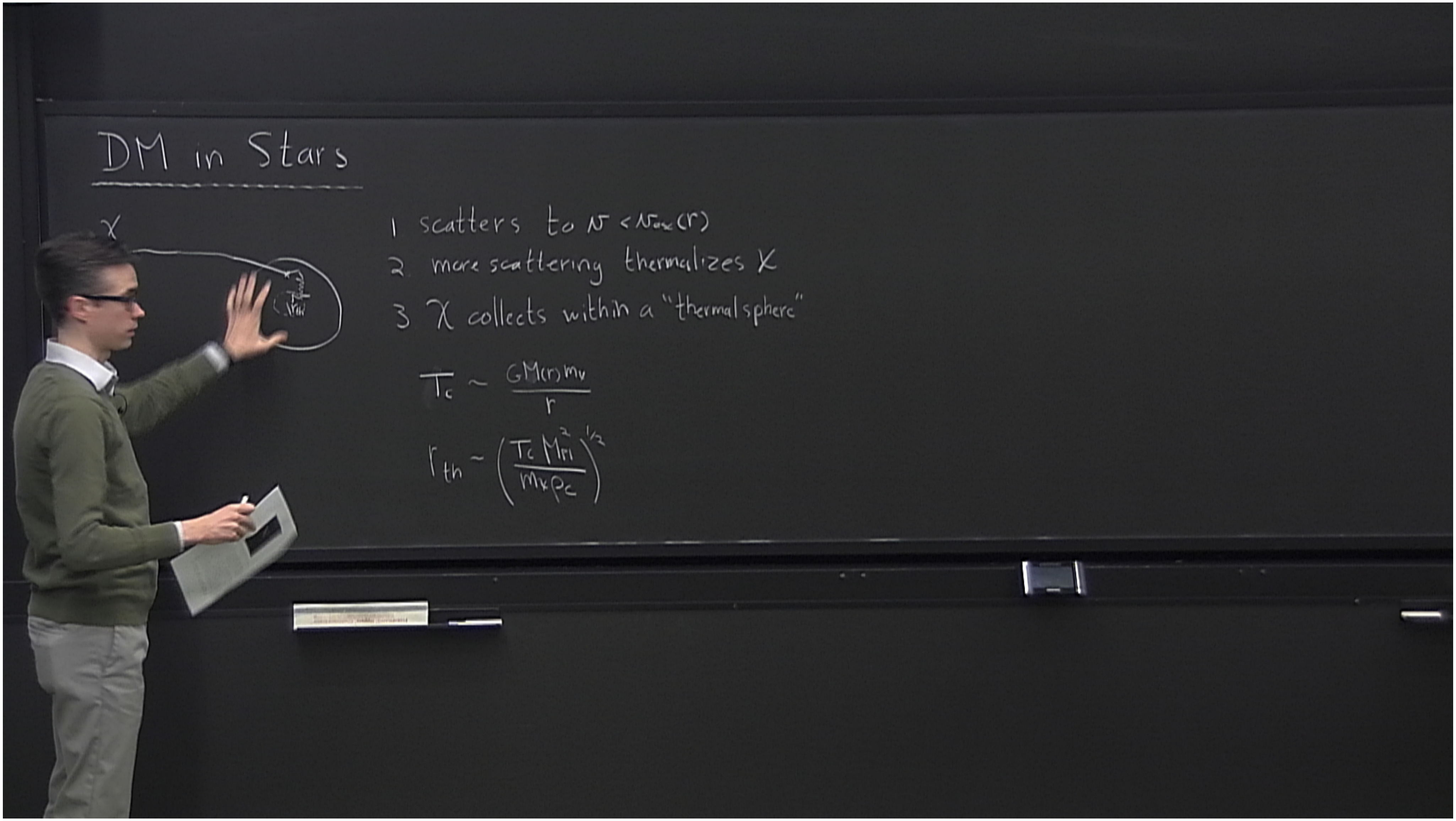
Date: Apr 04, 2013 10:15 AM

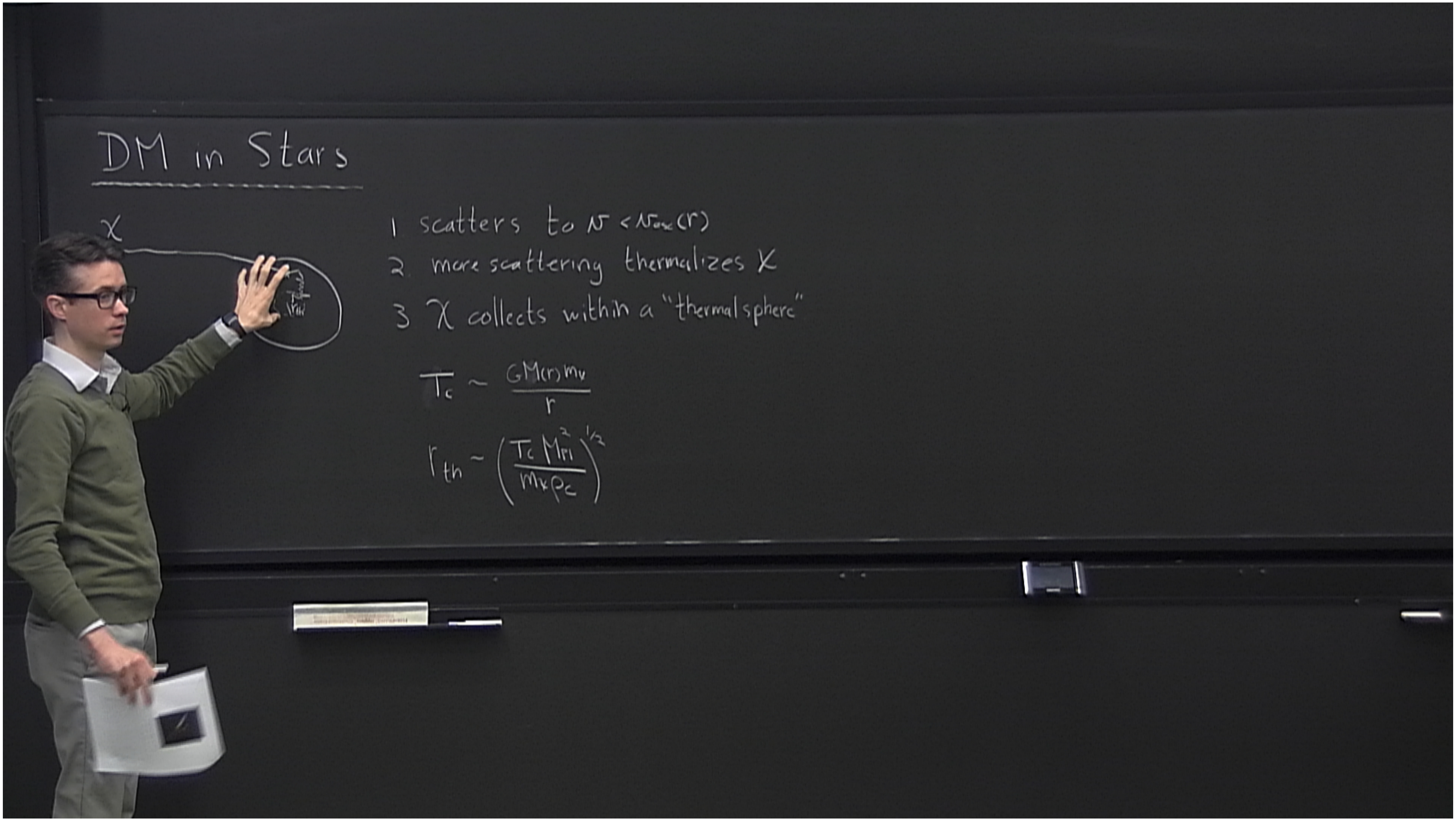
URL: http://pirsa.org/13040041

Abstract:


DM in Stars
χ


DM in Stars
χ
1 scatters to $v < v_{esc}(r)$
2. more scattering thermalizes χ


DM in Stars
χ
1 scatters to v < v_esc(r)
2. more scattering thermalizes χ
3 χ collects within a "thermal sphere"
T_c ~ GM(r) m_N / r
r_th ~ (T_c M_Pl^2 / m_χ ρ_c)^1/2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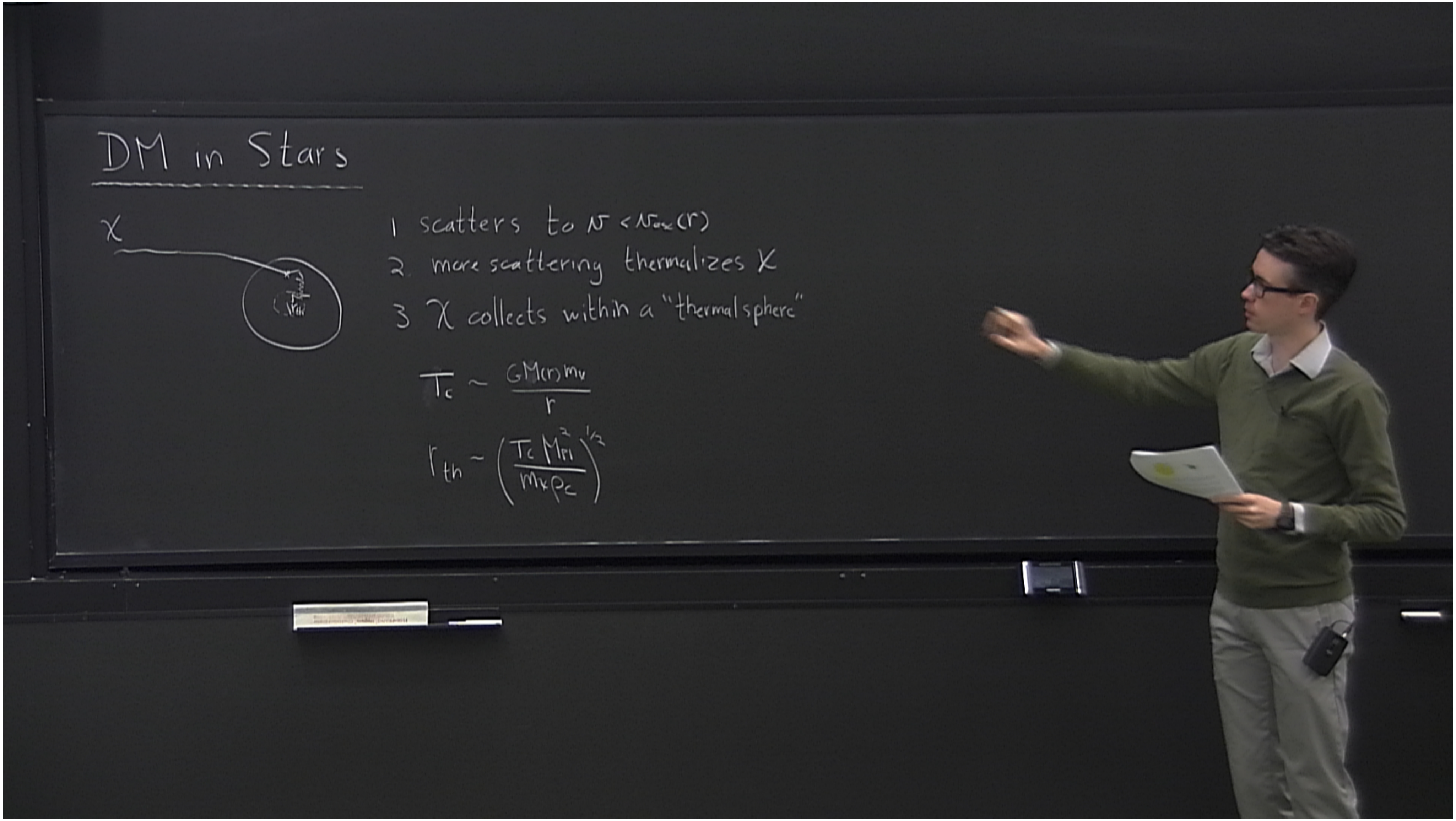
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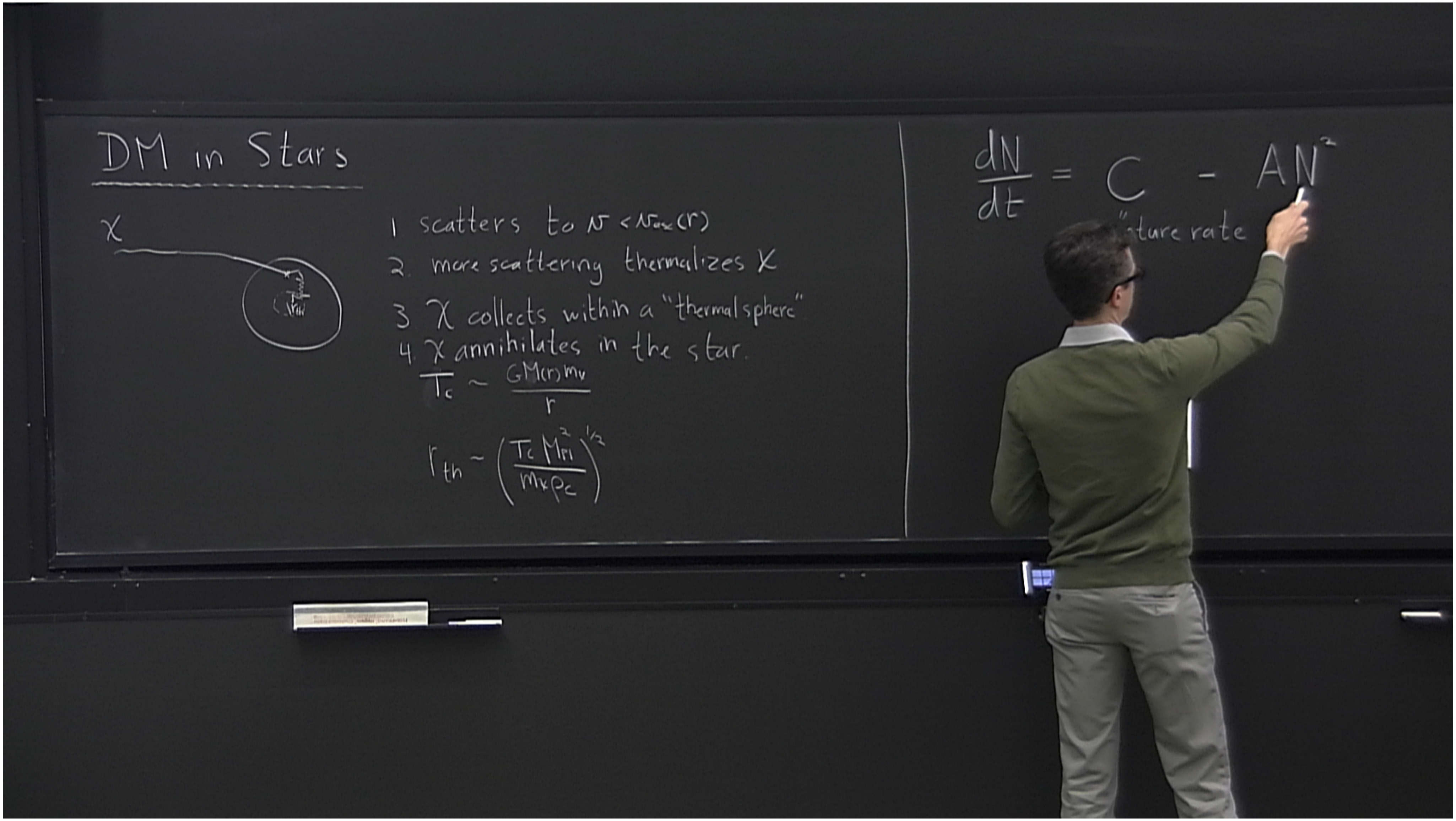
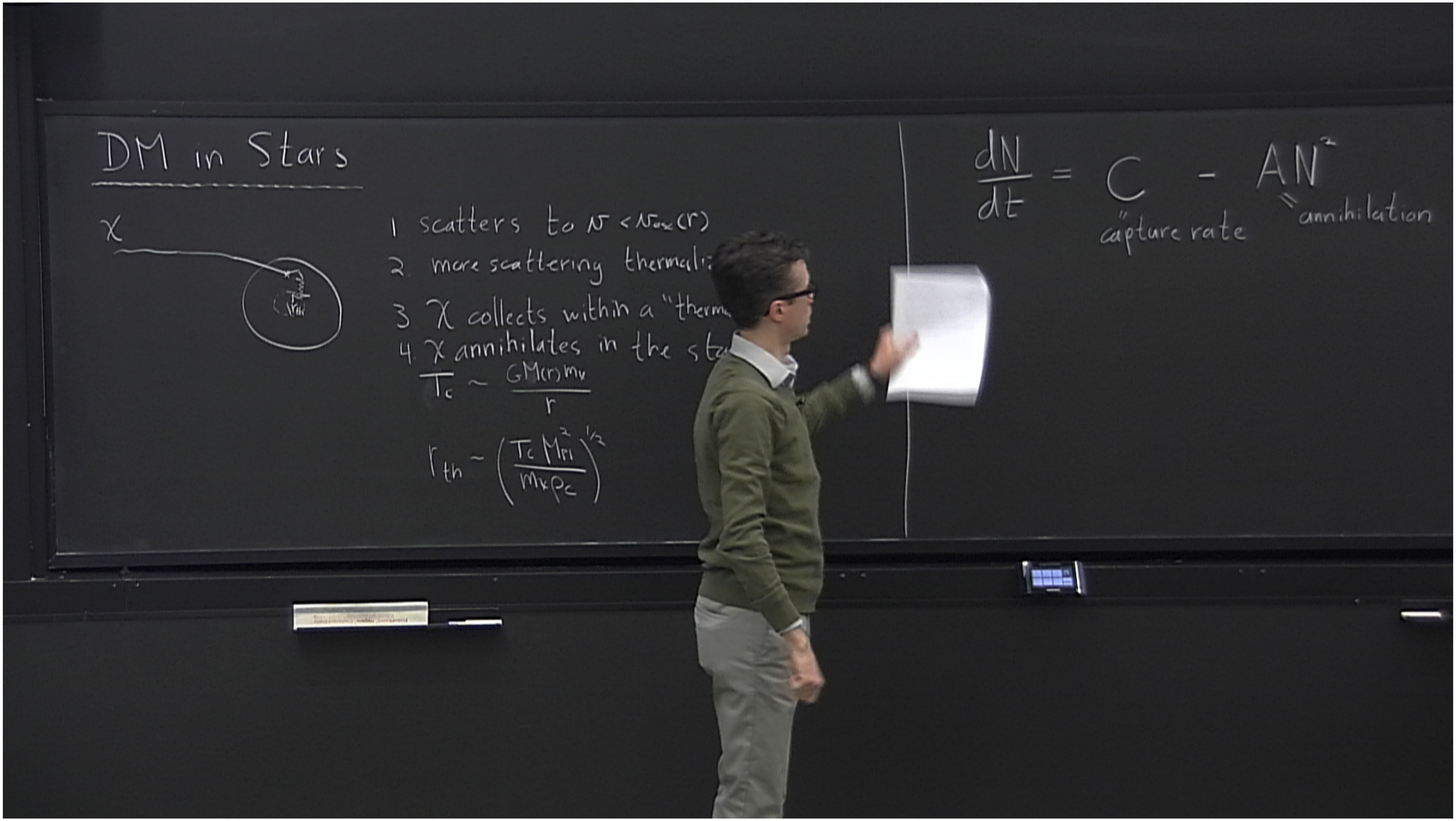

DM in Stars
χ
1 scatters to v < v_esc(r)
2. more scattering thermalizes χ
3 χ collects within a "thermal sphere"
4 χ annihilates in the star.
T_c ~ GM(r) m_v / r
r_th ~ (T_c M_Pl^2 / m_χ ρ_c)^(1/2)
dN/dt = C - AN^2
ture rate


DM in Stars
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T_c ~ GM(r)m_v / r
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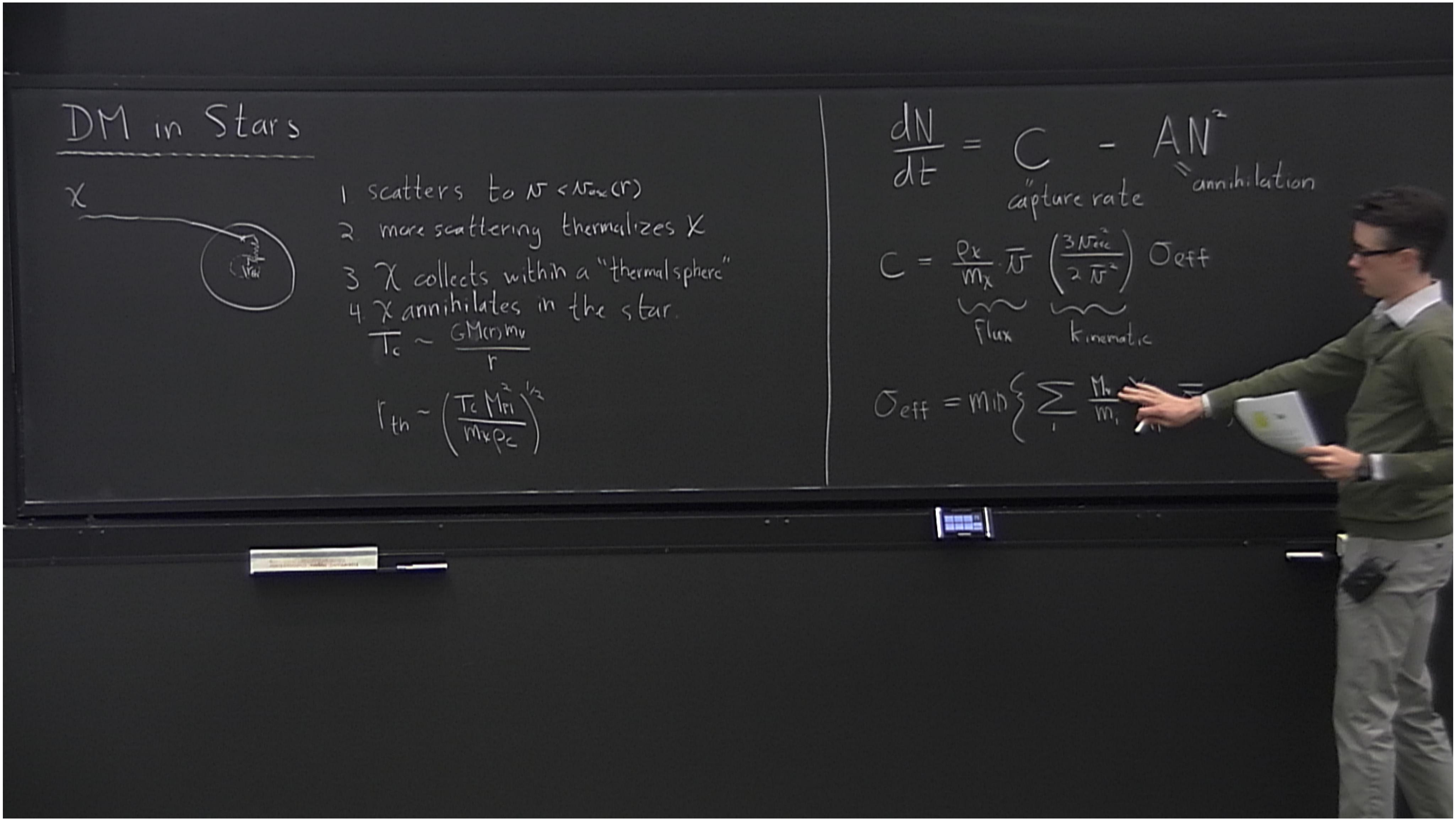
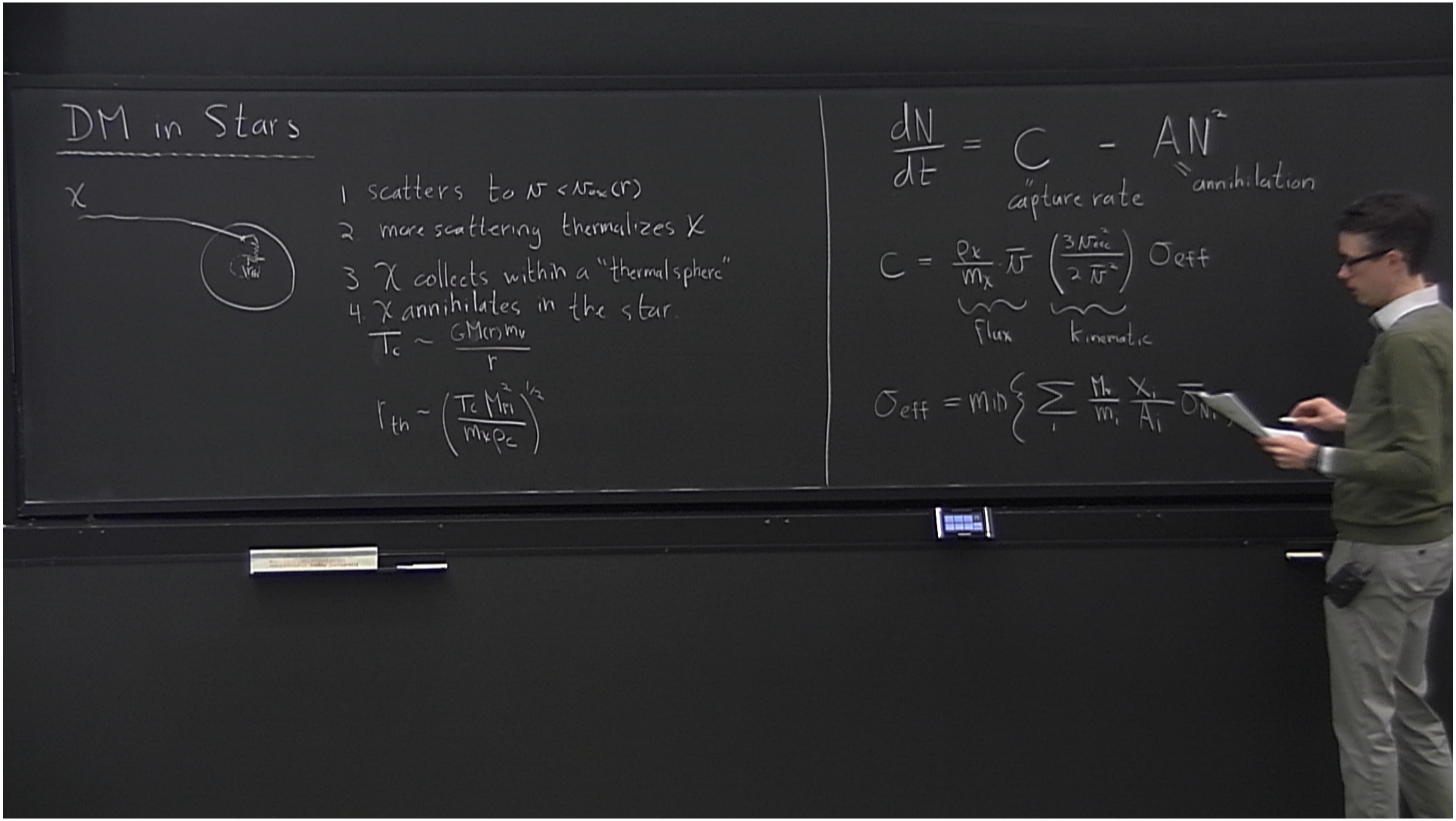
dN/dt = C - AN^2
capture rate
annihilation


DM in Stars
χ
1 scatters to $v < v_{esc}(r)$
2 more scattering thermalizes χ
3 χ collects within a "thermalsphere"
4. χ annihilates in the star.
$T_c \sim \frac{G M(r) m_n}{r}$
$r_{th} \sim \left(\frac{T_c M_{Pl}^2}{m_\chi \rho_c}\right)^{1/2}$
$\frac{dN}{dt} = C - A N^2$
capture rate
annihilation
$C = \frac{\rho_\chi}{m_\chi} \cdot \bar{v} \left(\frac{3 v_{esc}^2}{2 \bar{v}^2}\right) \sigma_{eff}$
flux
kinematic
$\sigma_{eff} = \min \{ \sum_i \frac{m_n}{m_i}$


DM in Stars
χ
1 scatters to $v < v_{esc}(r)$
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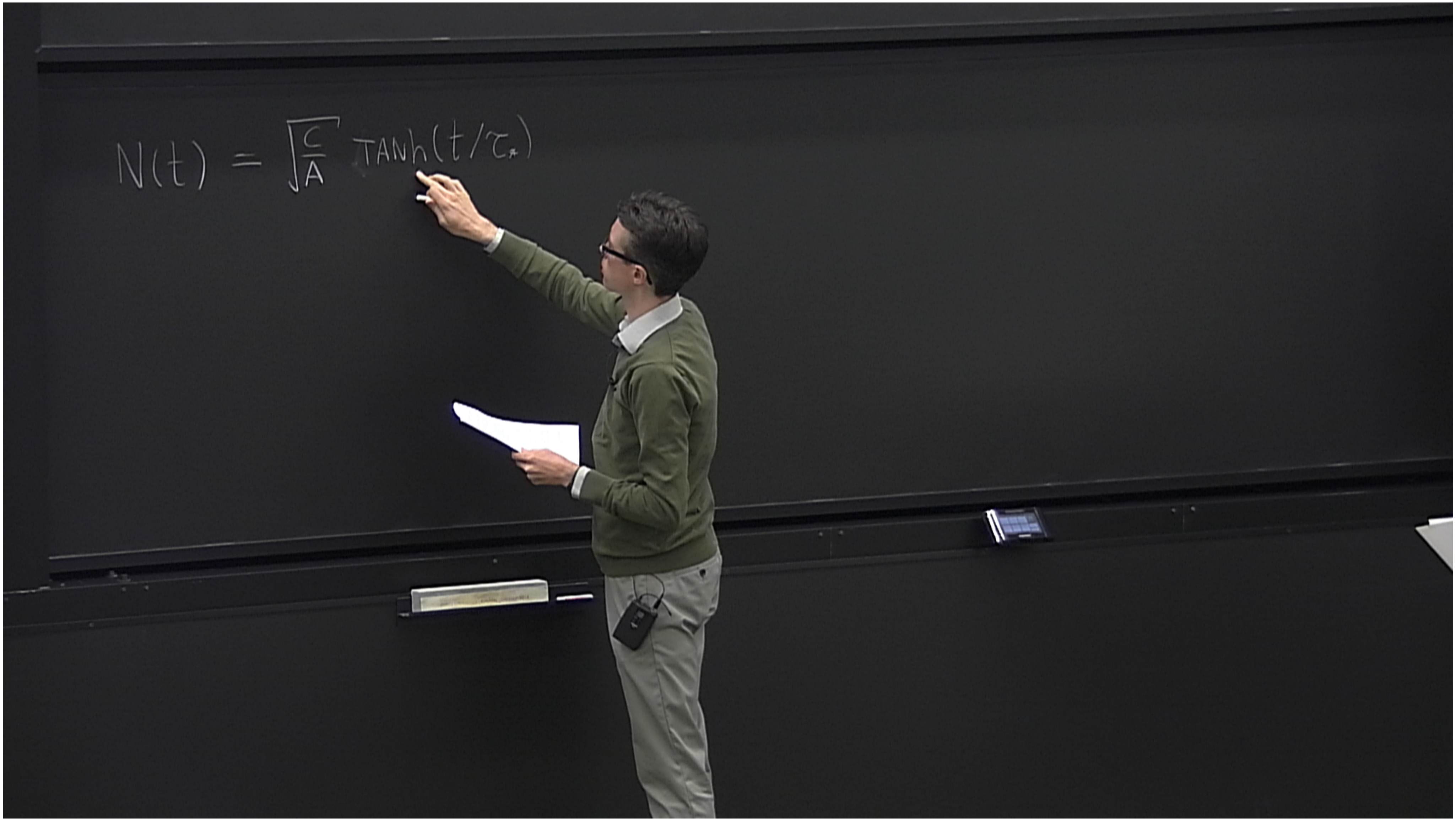
3 χ collects within a "thermal sphere"
4. χ annihilates in the star.
$T_c \sim \frac{GM(r) m_n}{r}$
$r_{th} \sim \left(\frac{T_c M_{Pl}^2}{m_\chi \rho_c}\right)^{1/2}$
$\frac{dN}{dt} = C - AN^2$
capture rate
annihilation
$C = \frac{\rho_\chi}{m_\chi} \cdot \bar{v} \left(\frac{3 v_{esc}^2}{2 \bar{v}^2}\right) \sigma_{eff}$
flux
kinematic
$\sigma_{eff} = \min\left\{ \sum_i \frac{M_*}{m_i} \frac{X_i}{A_i} \bar{\sigma}_N\right.$

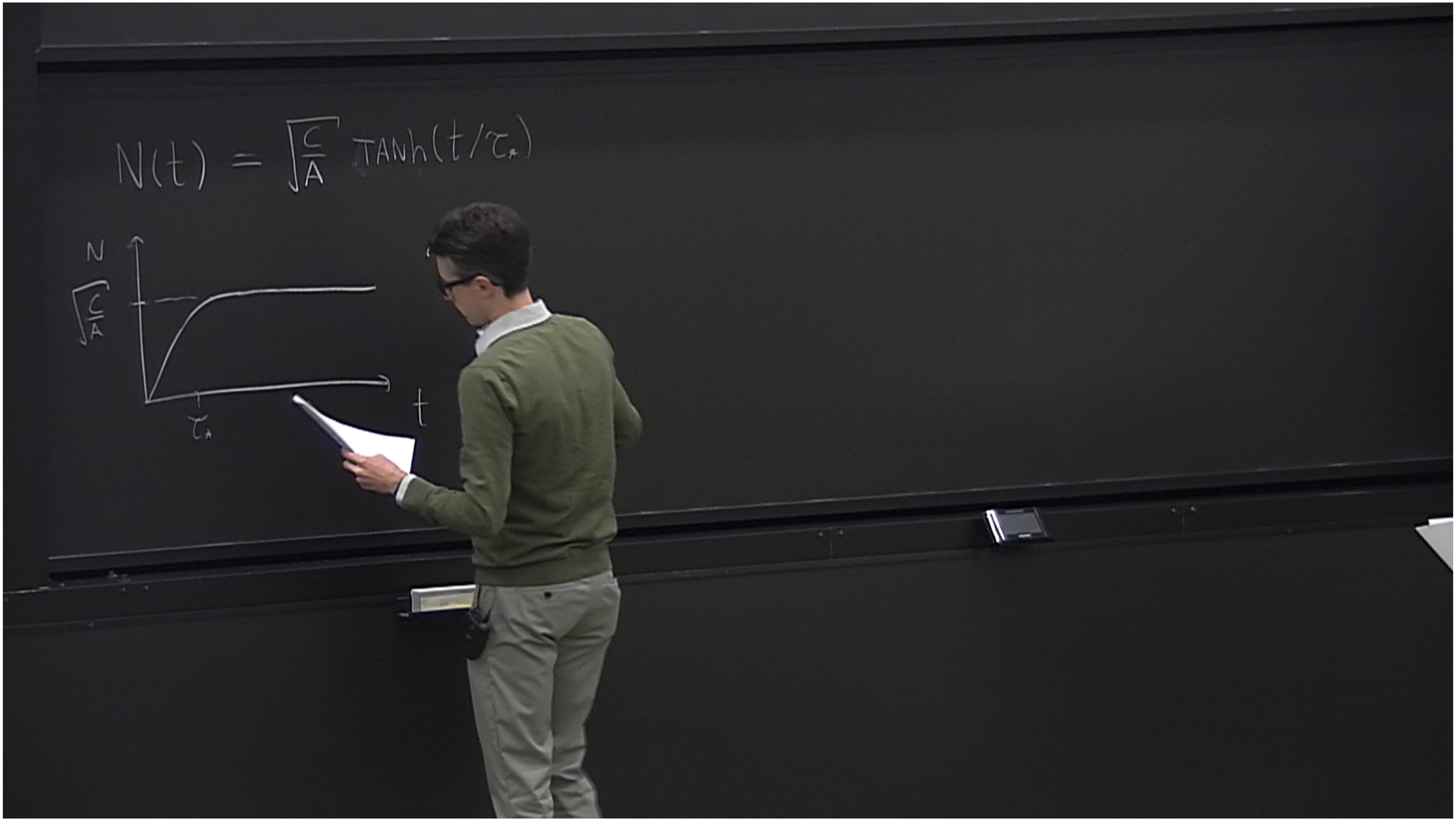
$$\frac{dN}{dt} = \underbrace{C}_{\text{capture rate}} - \underbrace{A}_{\text{annihilation}} N^2$$

$$C = \underbrace{\frac{\rho_\chi}{m_\chi} \cdot \bar{v}}_{\text{flux}} \underbrace{\left(\frac{3 v_{esc}^2}{2 \bar{v}^2}\right)}_{\text{kinematic}} \sigma_{eff}$$

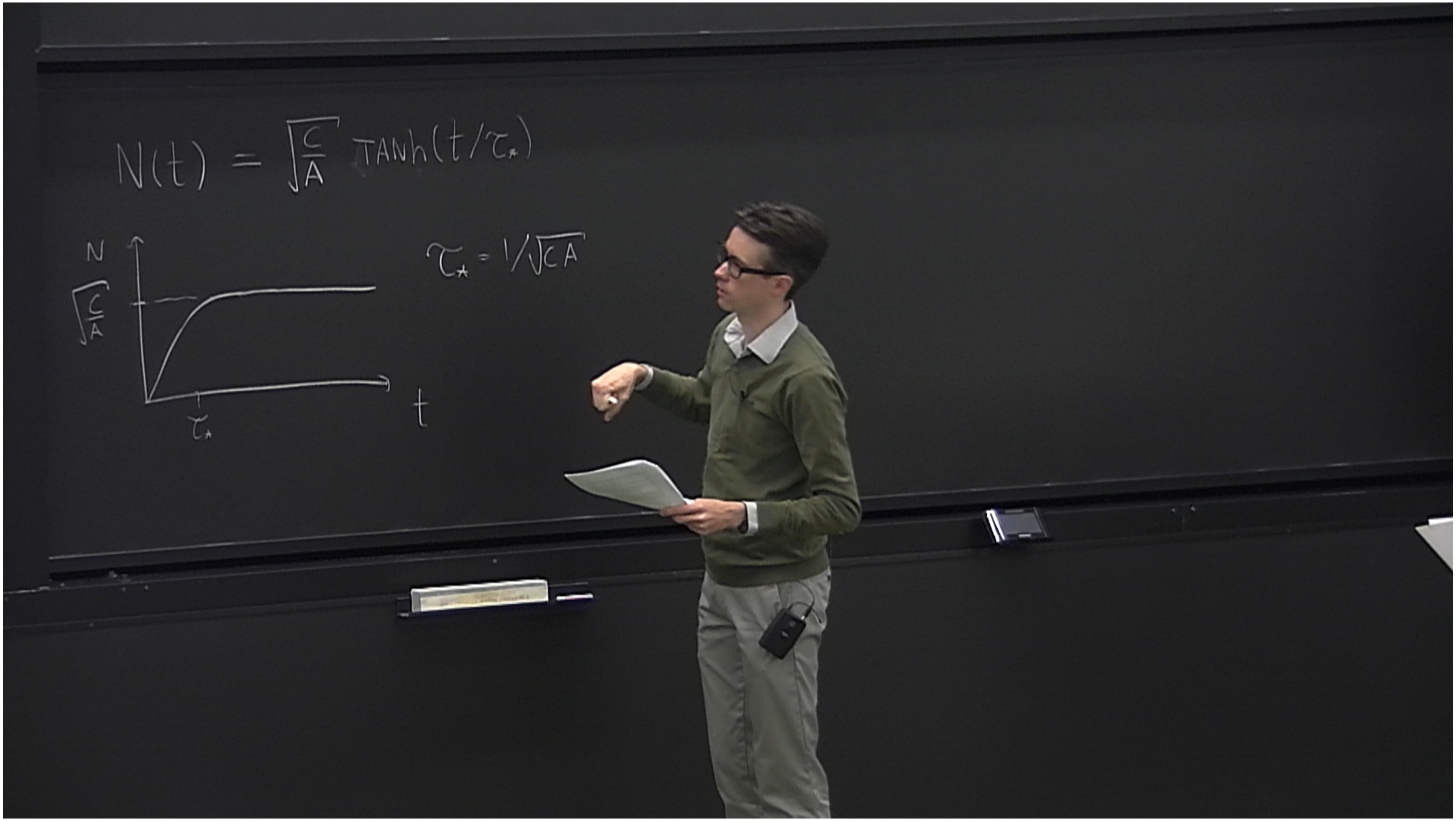
$$\sigma_{eff} = \min\left\{ \sum_i \frac{M_*}{m_i} \frac{X_i}{A_i} \bar{\sigma}_{N_i} ,\ \pi R_*^2 \right\}$$

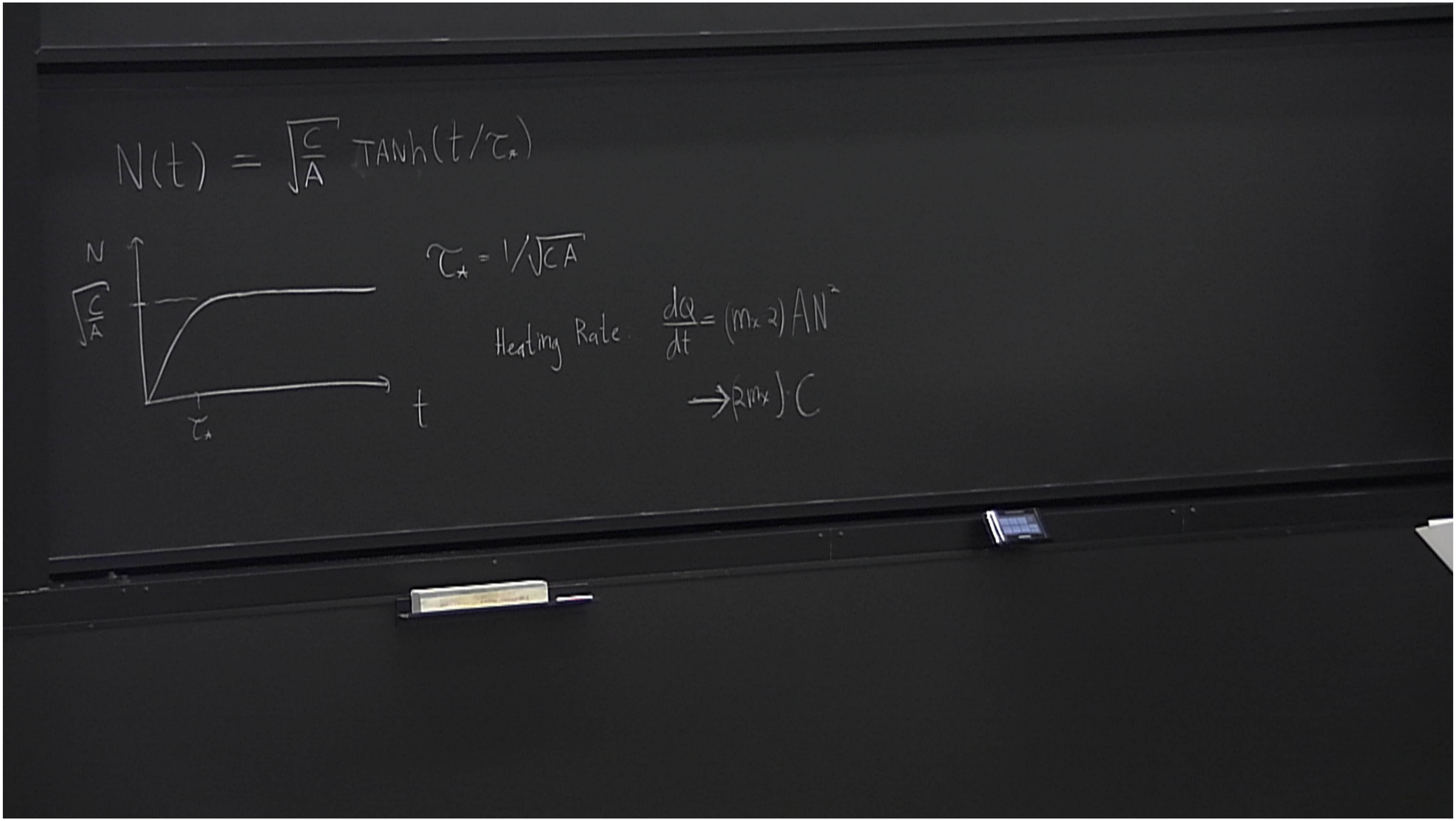
$$A = \langle \sigma v \rangle_{ann} \Big/ \left(\frac{4\pi}{3} r_{th}^3\right)$$


$N(t) = \sqrt{\frac{C}{A}}\, \mathrm{TANh}(t/\tau_*)$

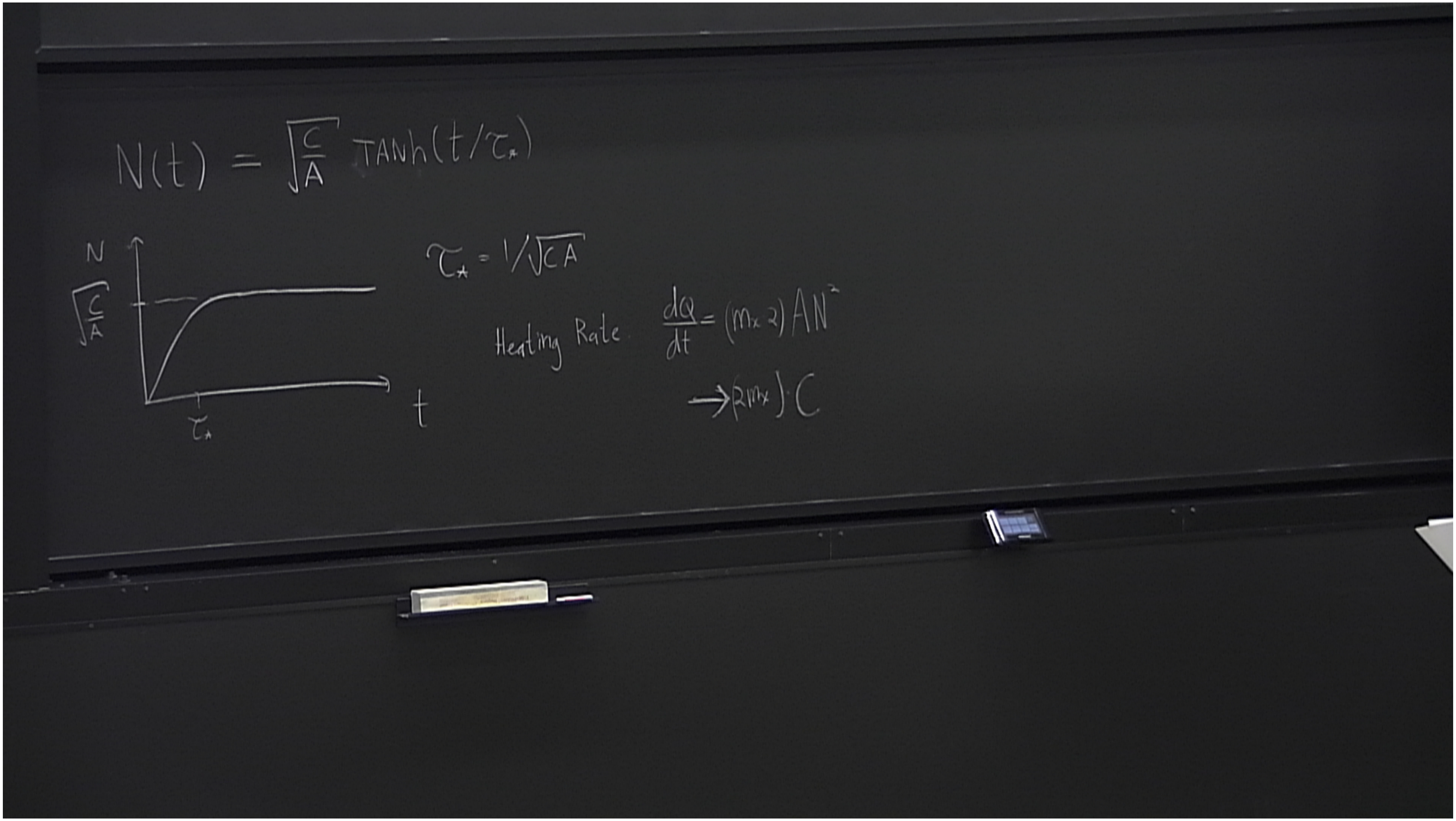


N(t) = √(C/A) TANh(t/τ*)
N
√(C/A)
τ*
t


N(t) = √(C/A) TANh(t/τ*)
N
√(C/A)
τ*
t
τ* = 1/√(CA)



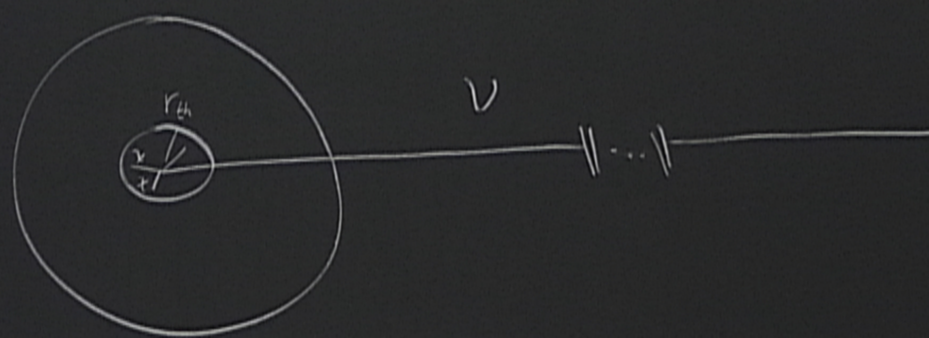
$N(t) = \sqrt{\frac{C}{A}}\,\mathrm{TANh}(t/\tau_*)$
N
$\sqrt{\frac{C}{A}}$
t
τ_*
$\tau_* = 1/\sqrt{CA}$
Heating Rate: $\frac{dQ}{dt} = (m_x 2) A N^2$
$\rightarrow (2m_x) \cdot C$

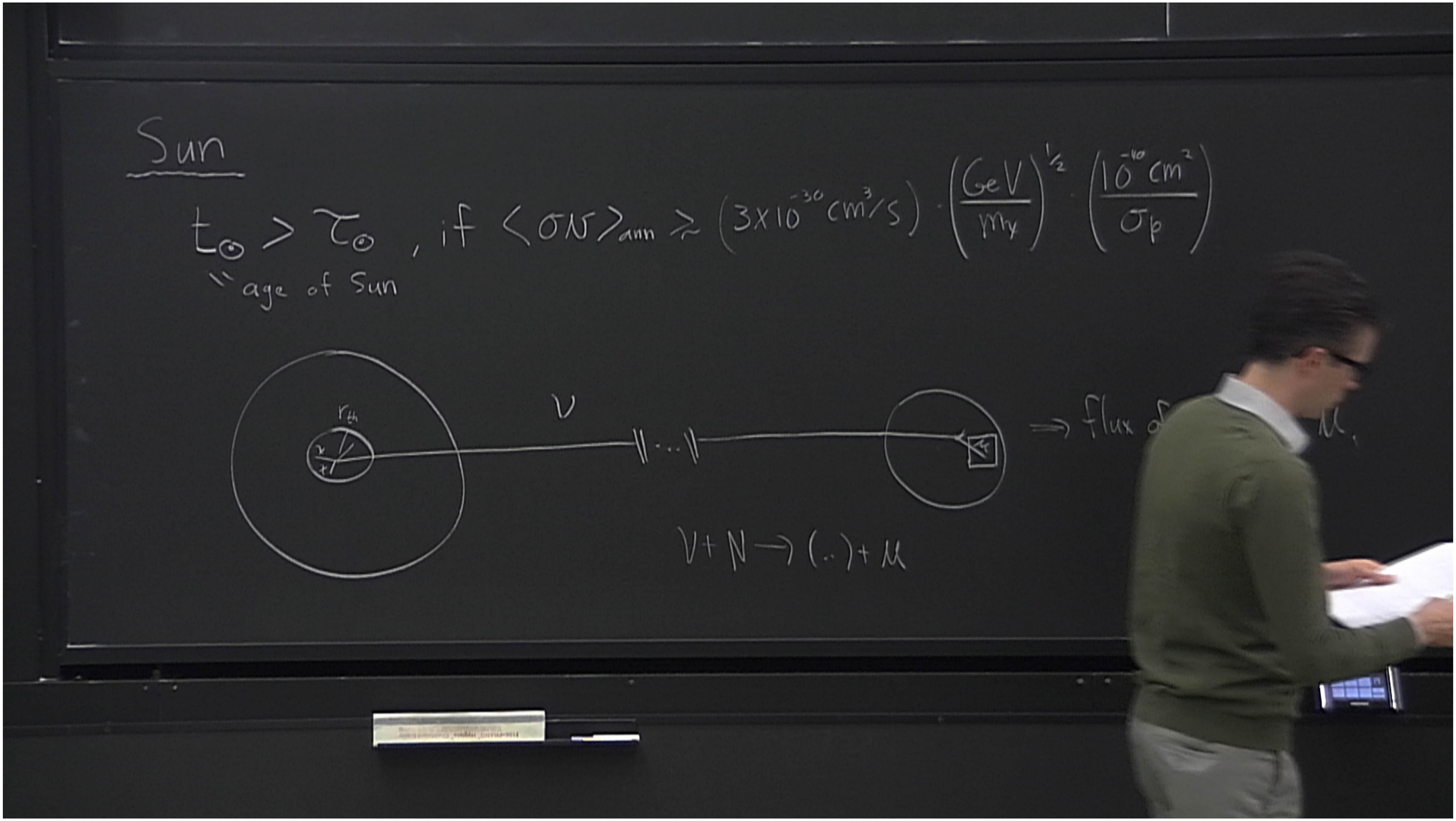

$N(t) = \sqrt{\frac{C}{A}}\, \mathrm{TANh}(t/\tau_*)$
N
$\sqrt{\frac{C}{A}}$
τ_*
t
$\tau_* = 1/\sqrt{CA}$
Heating Rate $\frac{dQ}{dt} = (m_\times 2) AN^2$
$\rightarrow (2m_\times)\cdot C$

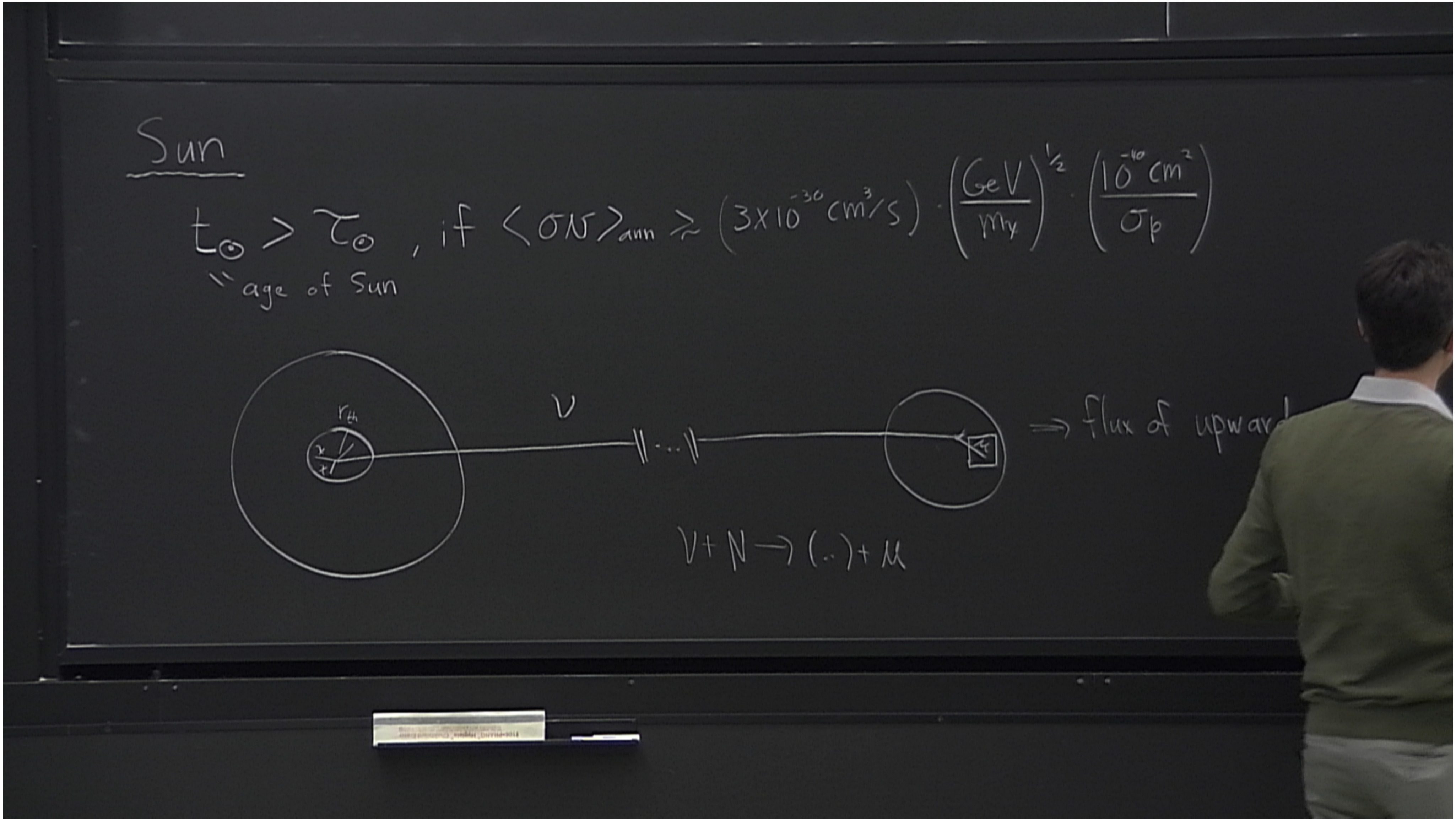
Sun

$$t_\odot > \tau_\odot \ , \text{ if } \langle \sigma v \rangle_{ann} \gtrsim \left(3\times10^{-30}\,\mathrm{cm}^3/\mathrm{s}\right)\cdot\left(\frac{\mathrm{GeV}}{m_\chi}\right)^{1/2}\cdot\left(\frac{10^{-40}\,\mathrm{cm}^2}{\sigma_p}\right)$$

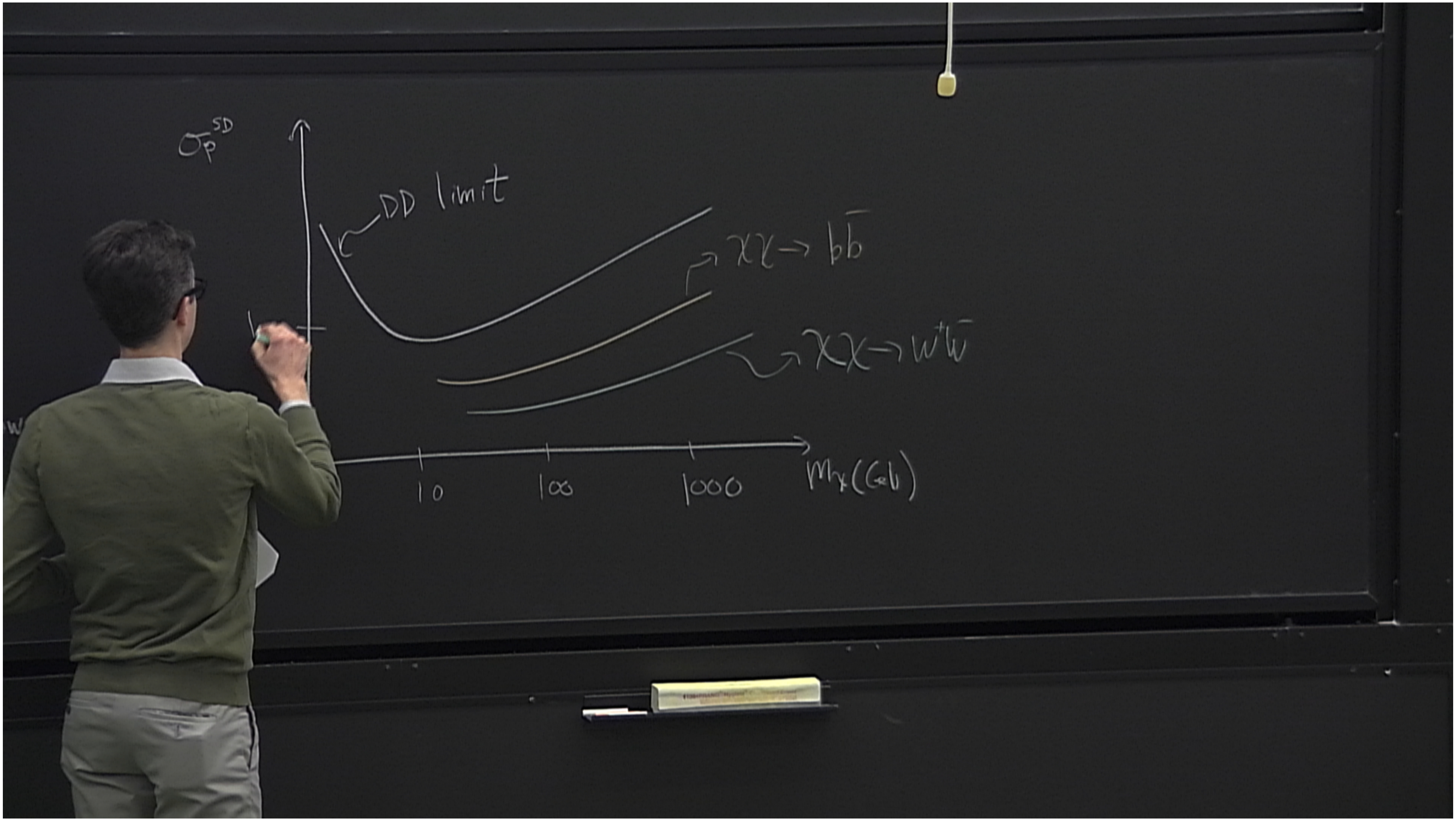
" age of Sun



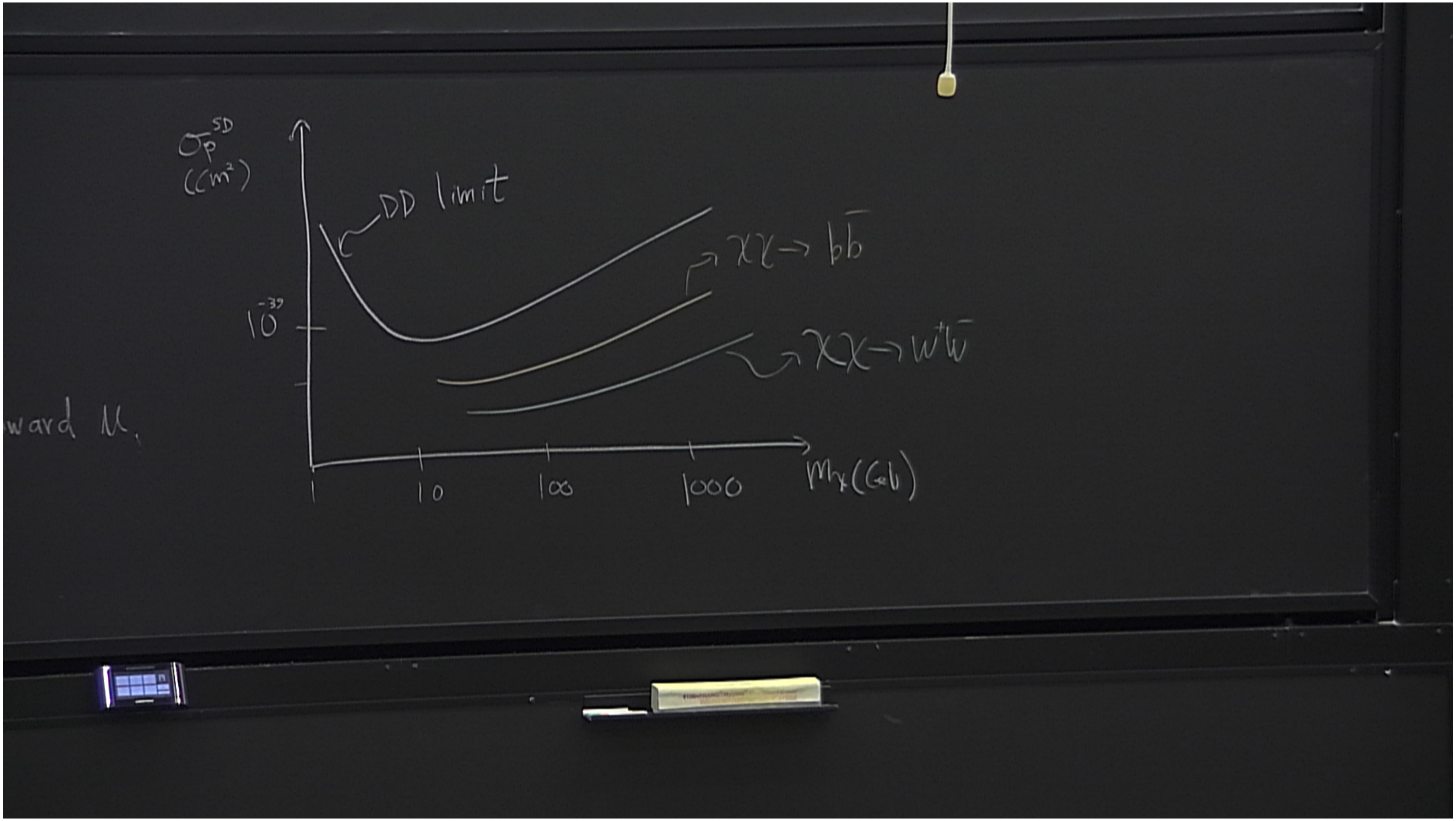

Sun
$t_\odot > \tau_\odot$, if $\langle \sigma v \rangle_{ann} \gtrsim (3\times 10^{-30}\, cm^3/s) \cdot \left(\frac{GeV}{m_\chi}\right)^{1/2} \cdot \left(\frac{10^{-40}\, cm^2}{\sigma_p}\right)$
age of Sun
r_{th}
ν
$\Longrightarrow$ flux
$\nu + N \rightarrow (..) + \mu$


Sun
$t_\odot > \tau_\odot$, if $\langle \sigma v \rangle_{ann} \gtrsim (3\times 10^{-30}\,cm^3/s) \cdot \left(\frac{GeV}{m_\chi}\right)^{1/2} \cdot \left(\frac{10^{-40}\,cm^2}{\sigma_p}\right)$
age of Sun
r_{th}
ν
$\Rightarrow$ flux of upward
$\nu + N \rightarrow (..) + \mu$


ward M.



σ_p^{SD}
DD limit
$\chi\chi \to b\bar{b}$
$\chi\chi \to W^+W^-$
10
100
1000
m_χ (GeV)

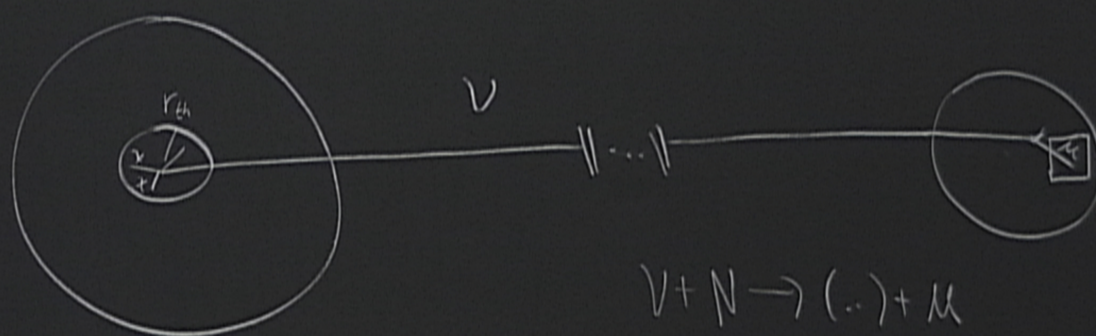


σ_p^SD
(cm²)
DD limit
10^-39
χχ → bb̄
χχ → W⁺W⁻
1
10
100
1000
m_χ (GeV)
ward M.

Sun

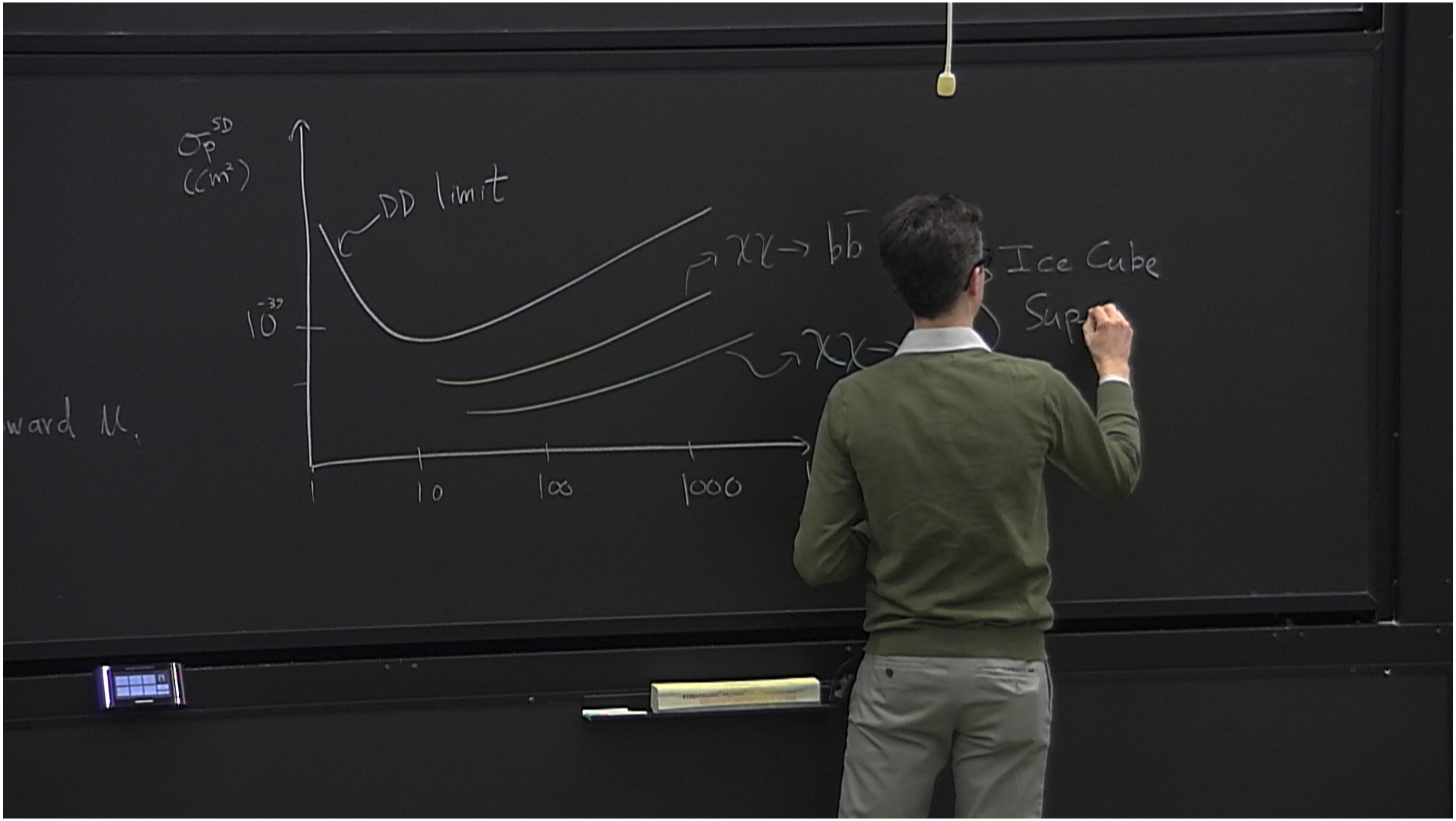
$$t_\odot > \tau_\odot \;, \text{ if } \langle \sigma v \rangle_{ann} \gtrsim (3\times10^{-30}\,\mathrm{cm^3/s}) \cdot \left(\frac{\mathrm{GeV}}{m_\chi}\right)^{1/2} \cdot \left(\frac{10^{-40}\,\mathrm{cm}^2}{\sigma_p}\right)$$

"age of Sun

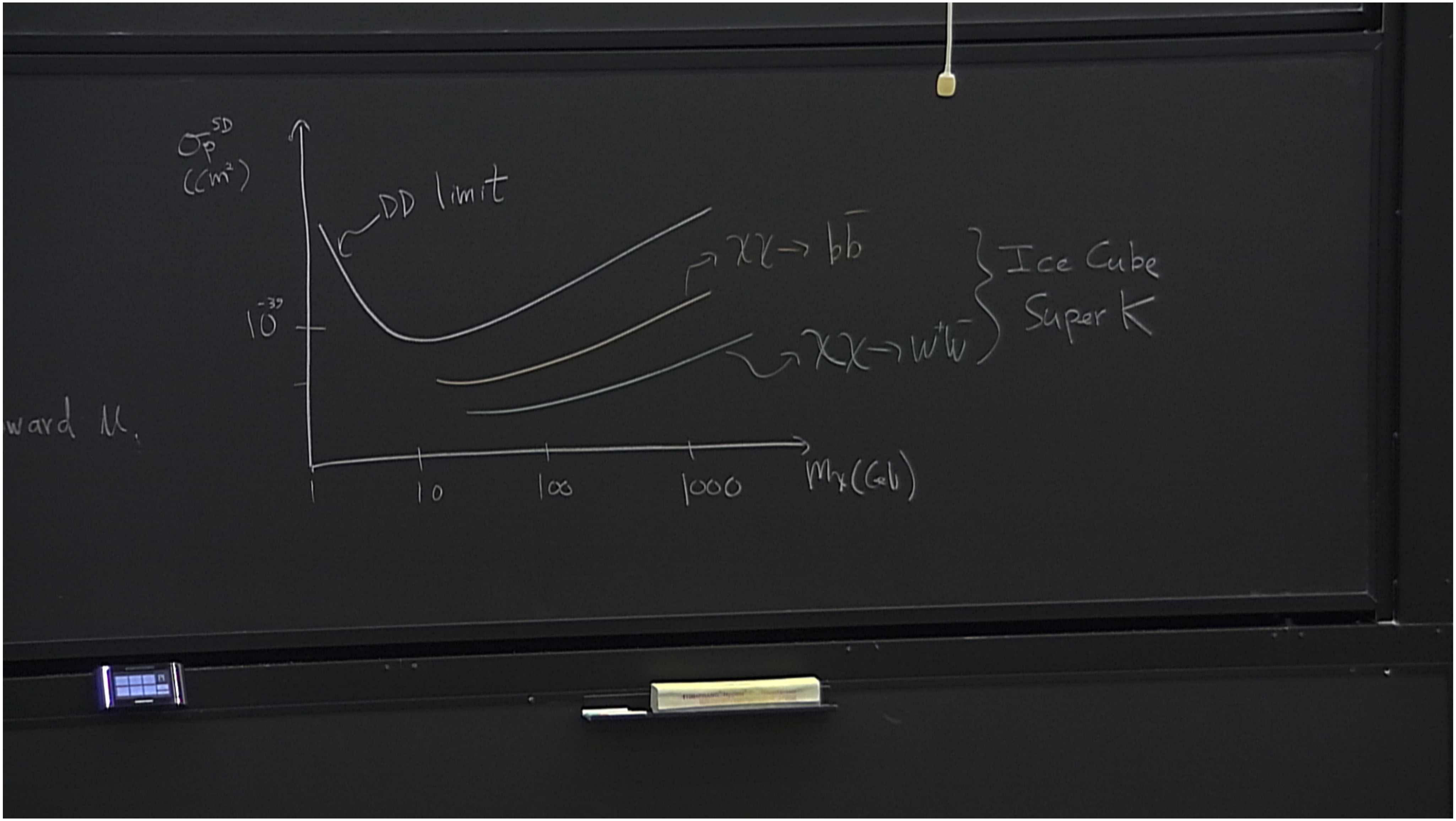


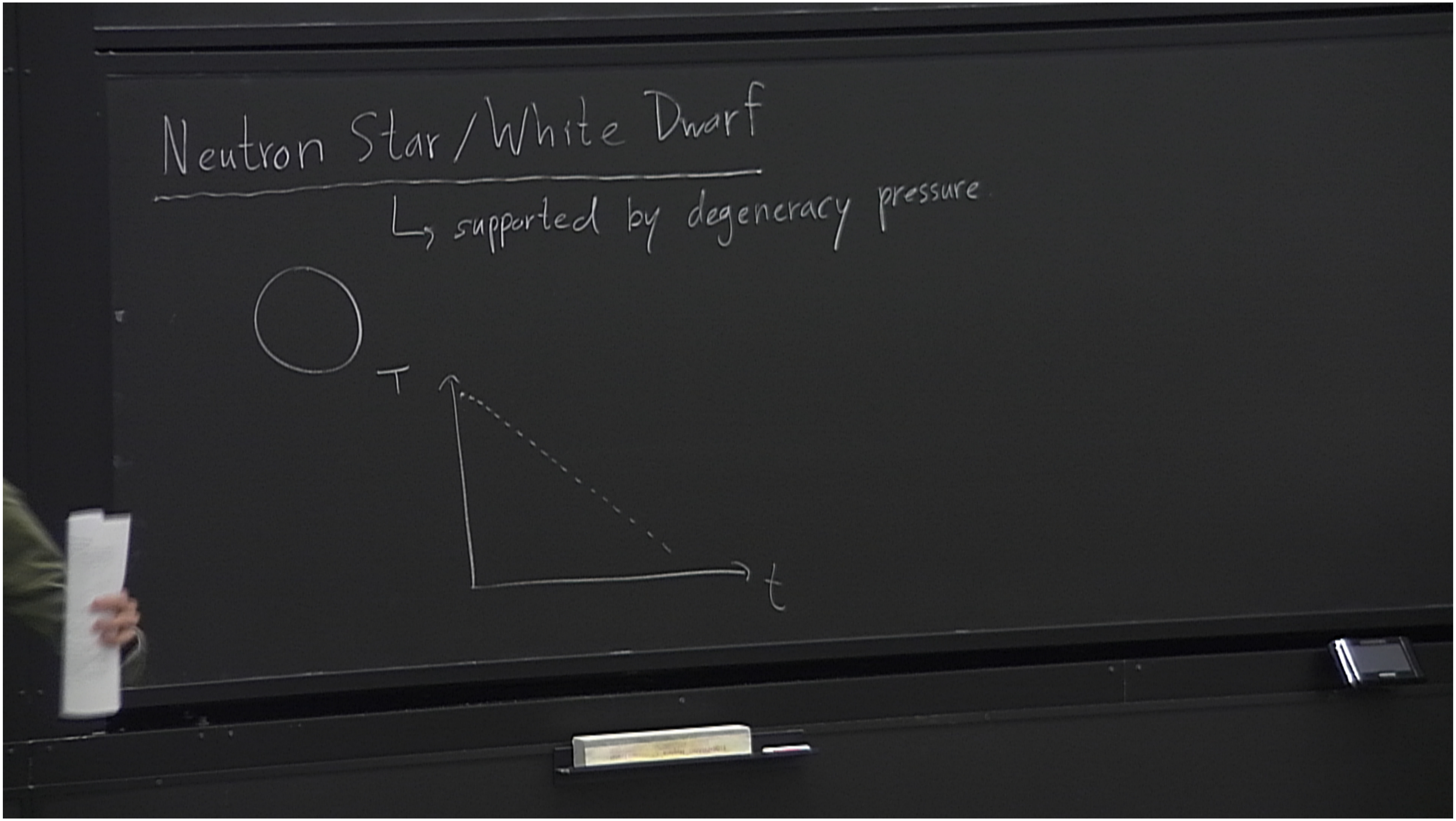
$\Rightarrow$ flux of upward μ.

$$\nu + N \to (\ldots) + \mu$$

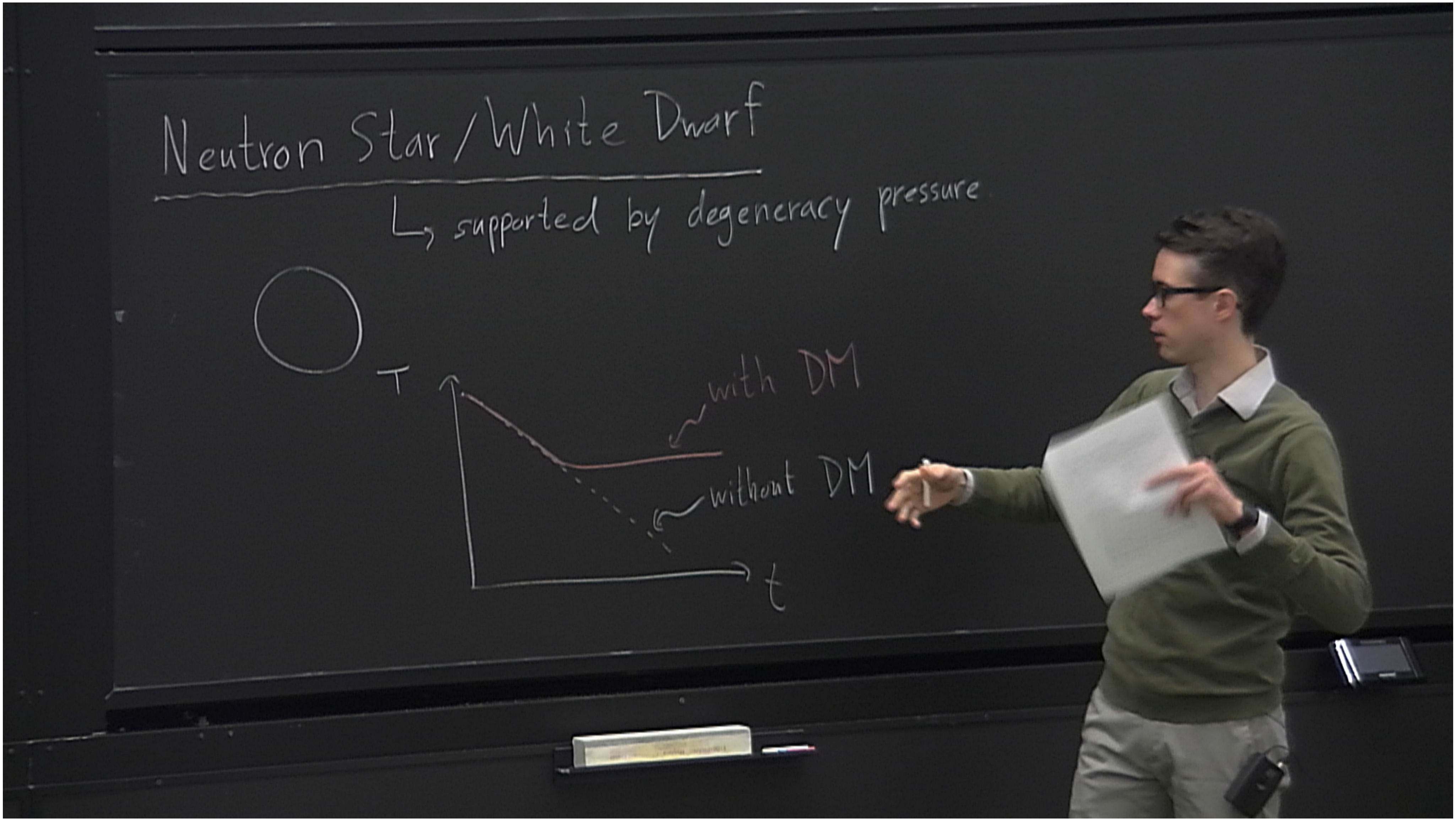


σ_p^{SD}
(cm^2)
DD limit
10^{-39}
$\chi\chi \to b\bar{b}$
Ice Cube
Sup
$\chi\chi \to$
ward M.
1
10
100
1000

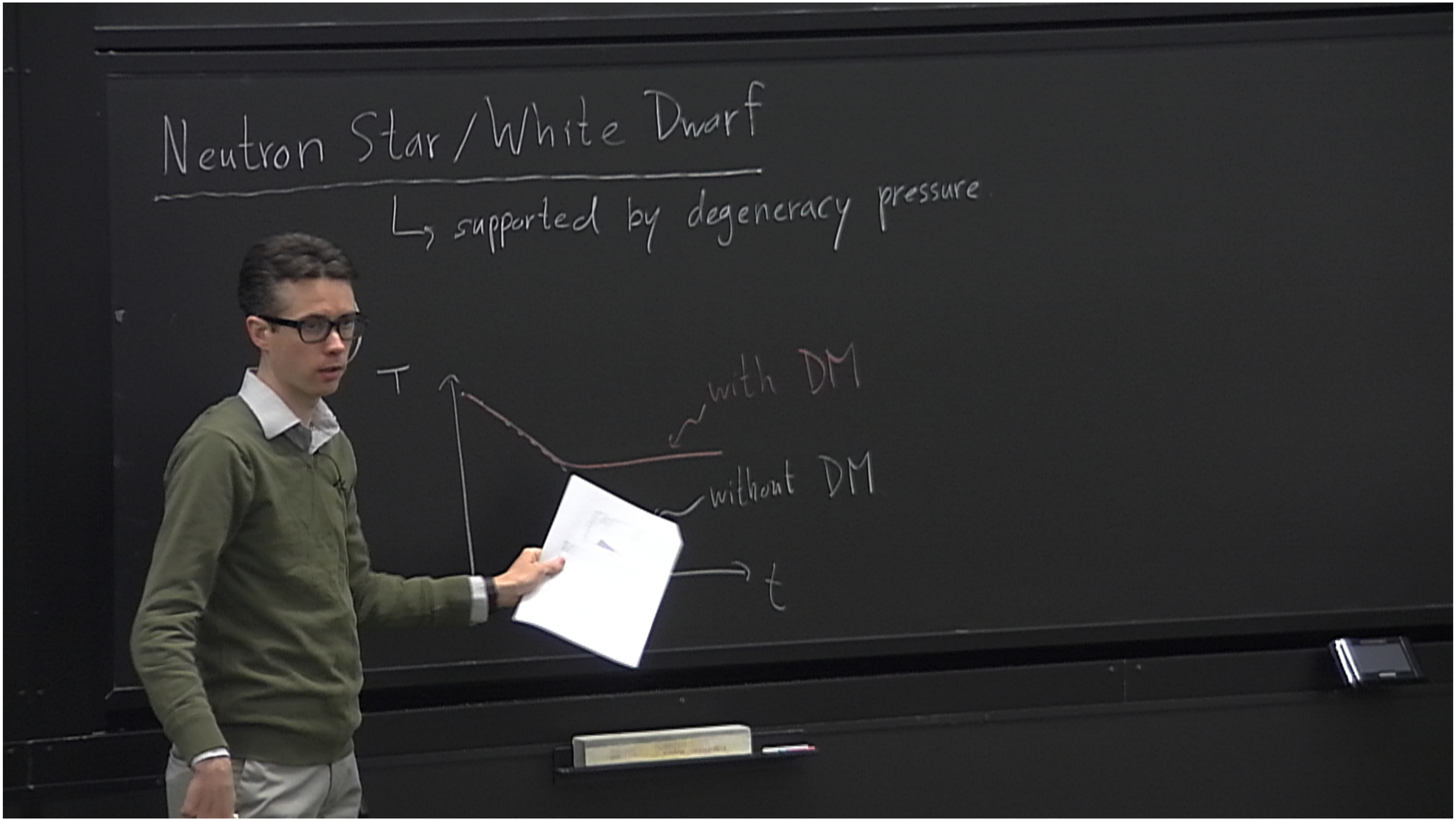

σ_p^{SD} (cm²)
DD limit
10^{-39}
χχ → $b\bar{b}$
χχ → W^+W^-
Ice Cube
Super K
1
10
100
1000
m_χ (GeV)
ward μ.


Neutron Star / White Dwarf
↳ supported by degeneracy pressure.
T
t


Neutron Star / White Dwarf
↳ supported by degeneracy pressure.
T
with
without

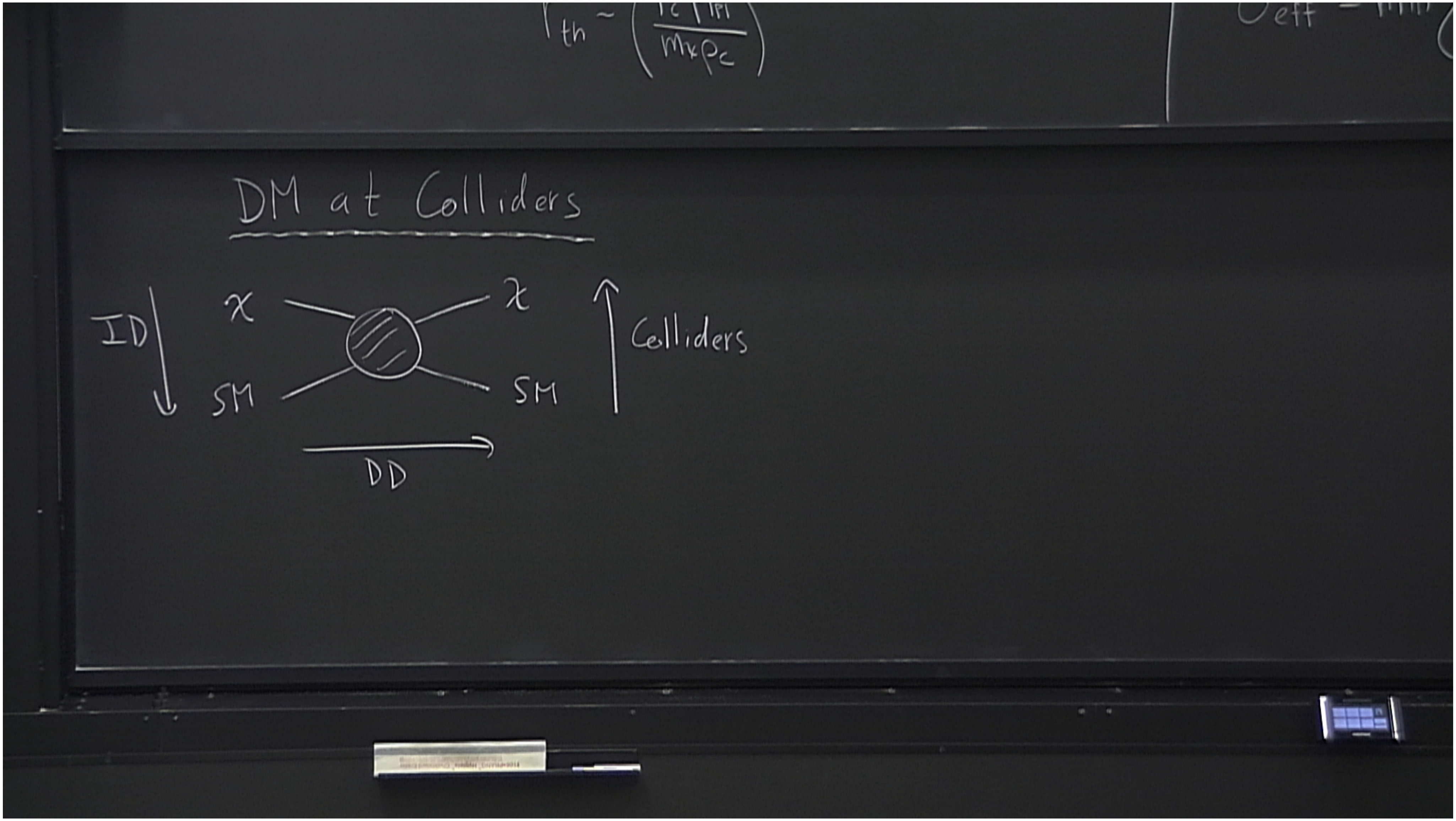

Neutron Star / White Dwarf
↳ supported by degeneracy pressure
T
with DM
without DM
t

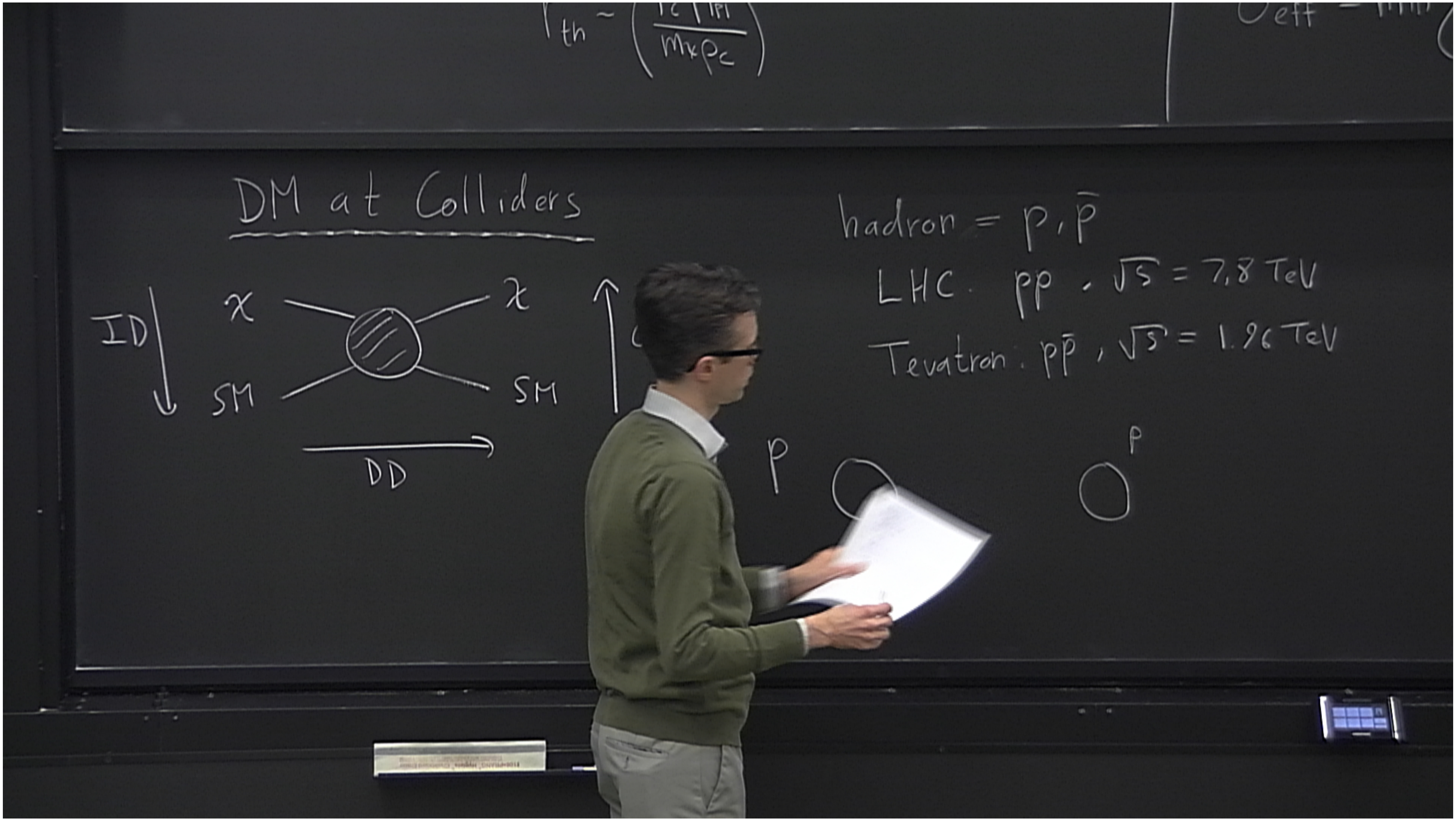

Neutron Star / White Dwarf
↳ supported by degeneracy pressure
T
with DM
t


Neutron Star / White Dwarf
↳ supported by degeneracy pressure
T
with DM
without DM
t


Neutron Star / White Dwarf
↳ supported by degeneracy pressure
T
with DM
without DM
t

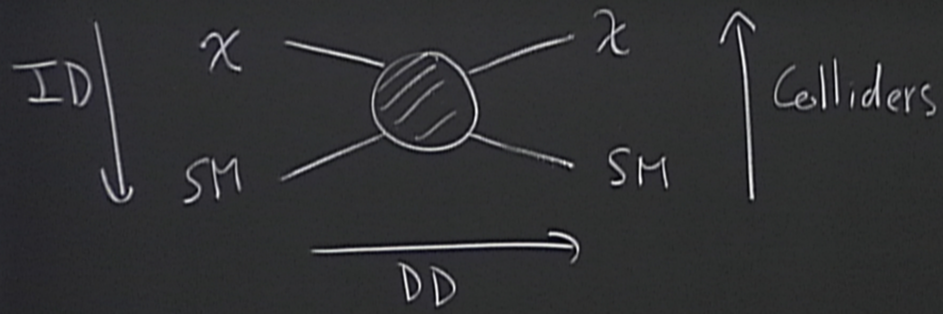

Neutron Star / White Dwarf
↳ supported by degeneracy pressure
T
with DM
without DM
t


DM at Colliders
ID
χ
χ
Colliders
SM
SM
DD


DM at Colliders
ID
χ
SM
DD
hadron = p, p̄
LHC: pp, √s = 7,8 TeV
Tevatron: pp̄, √s = 1.96 TeV
p

$r_{th} \sim \left(\frac{\ldots}{m_\chi \rho_c} \right)$ $\sigma_{eff} = \min$

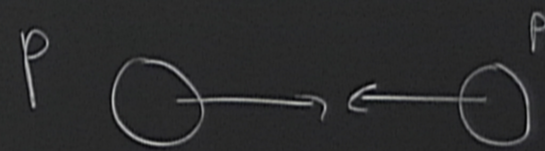
DM at Colliders

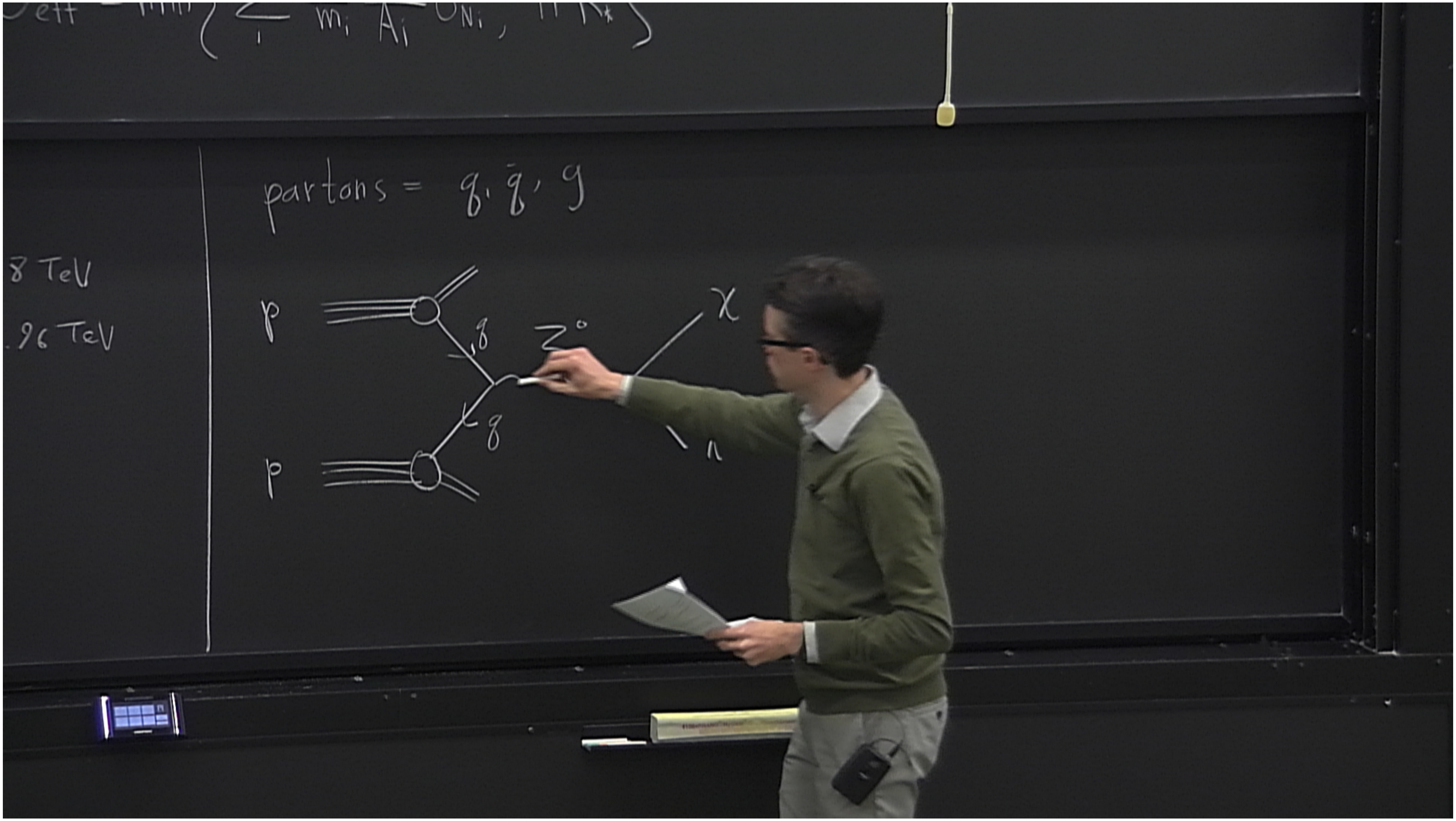


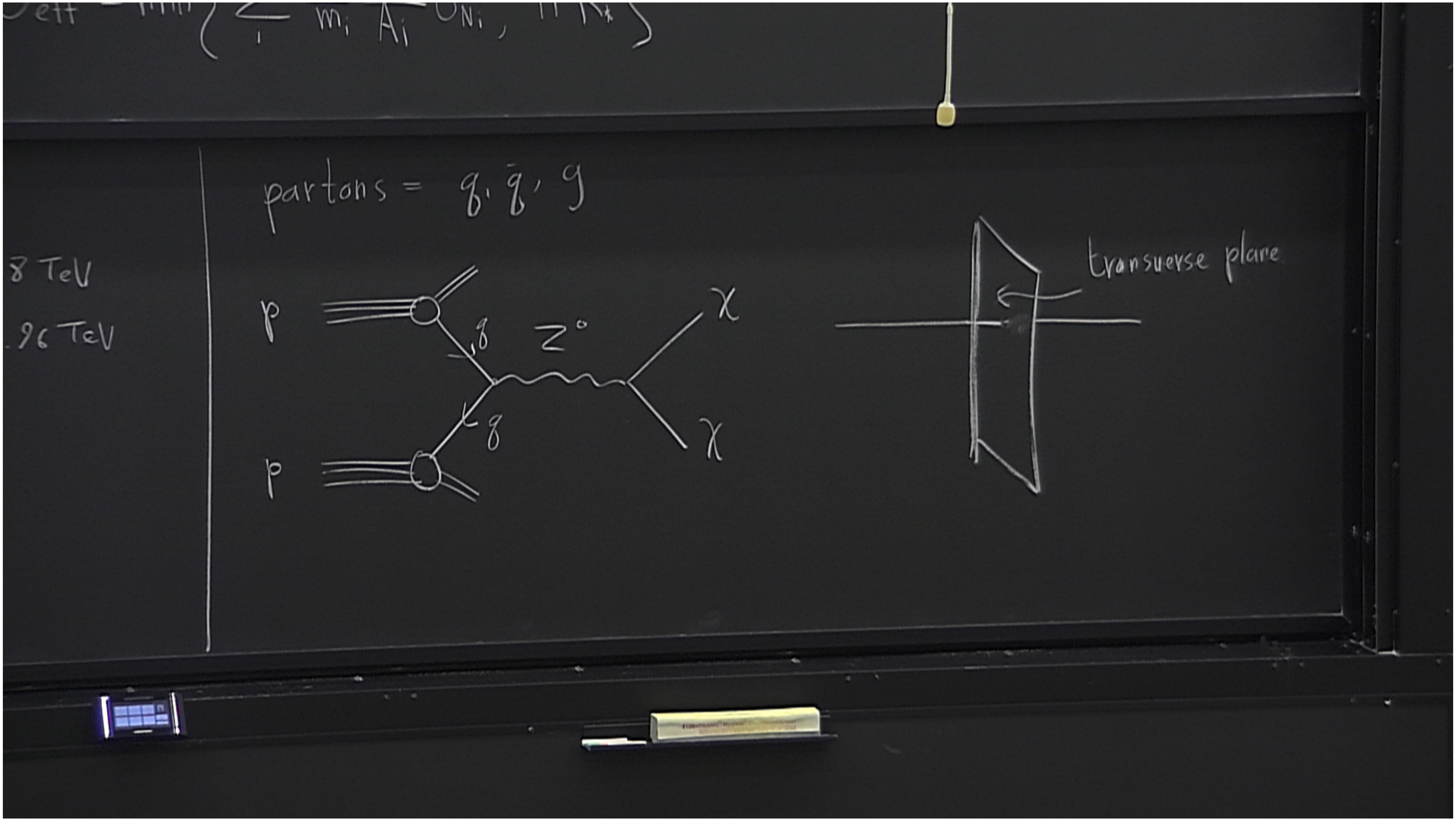
hadron = $p, \bar{p}$

LHC: pp, $\sqrt{s} = 7, 8$ TeV

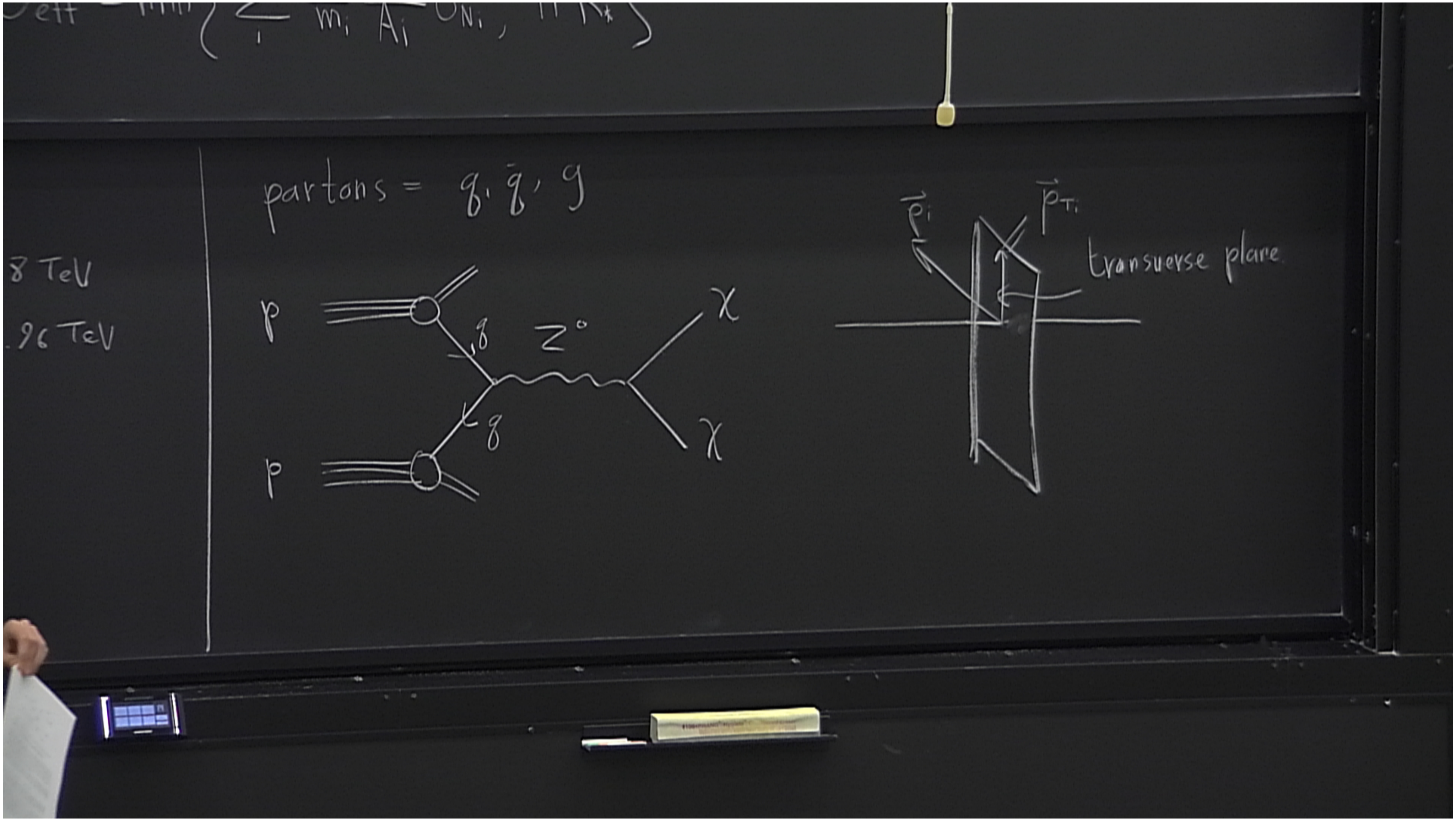
Tevatron: $p\bar{p}$, $\sqrt{s} = 1.96$ TeV

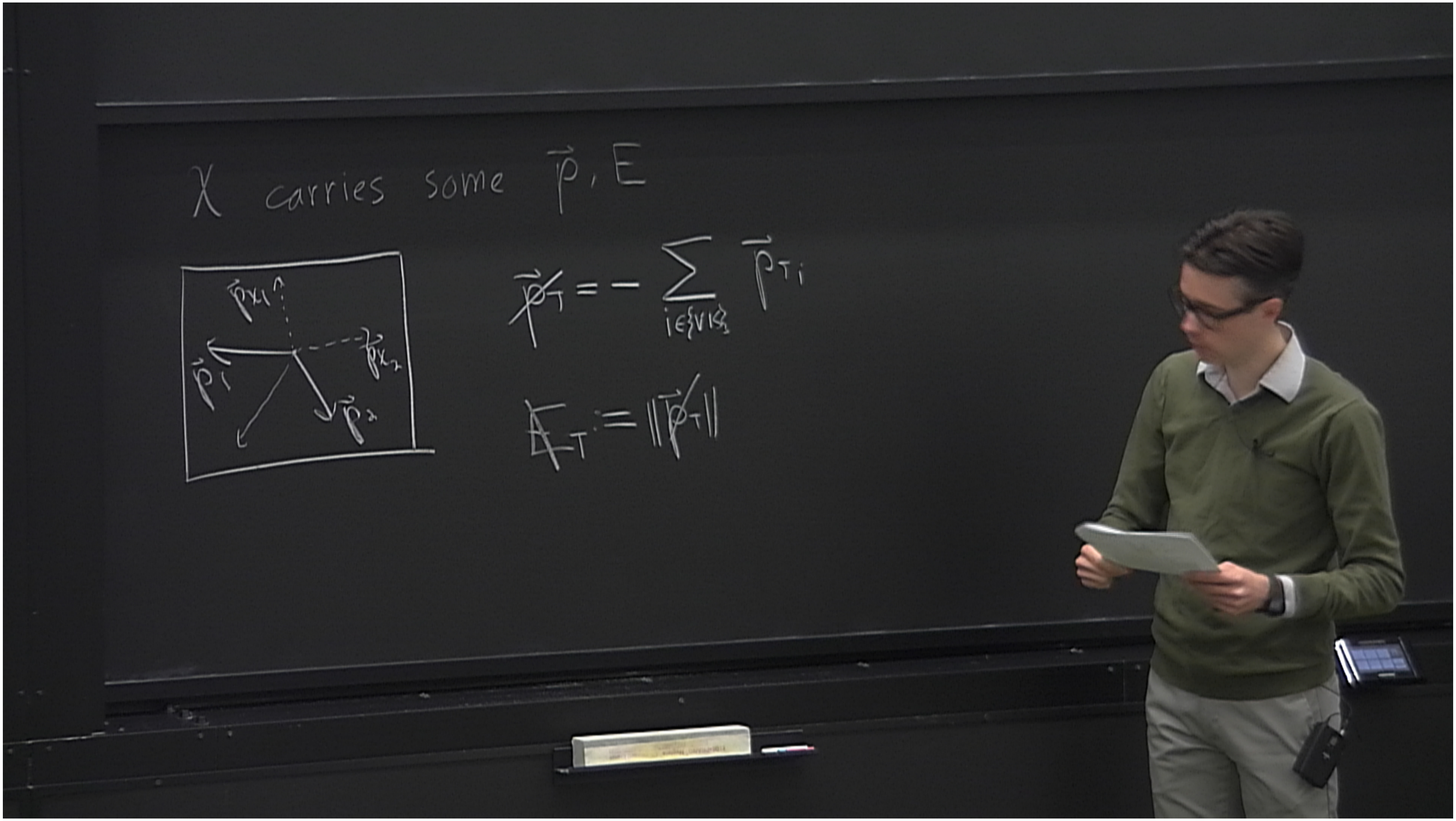


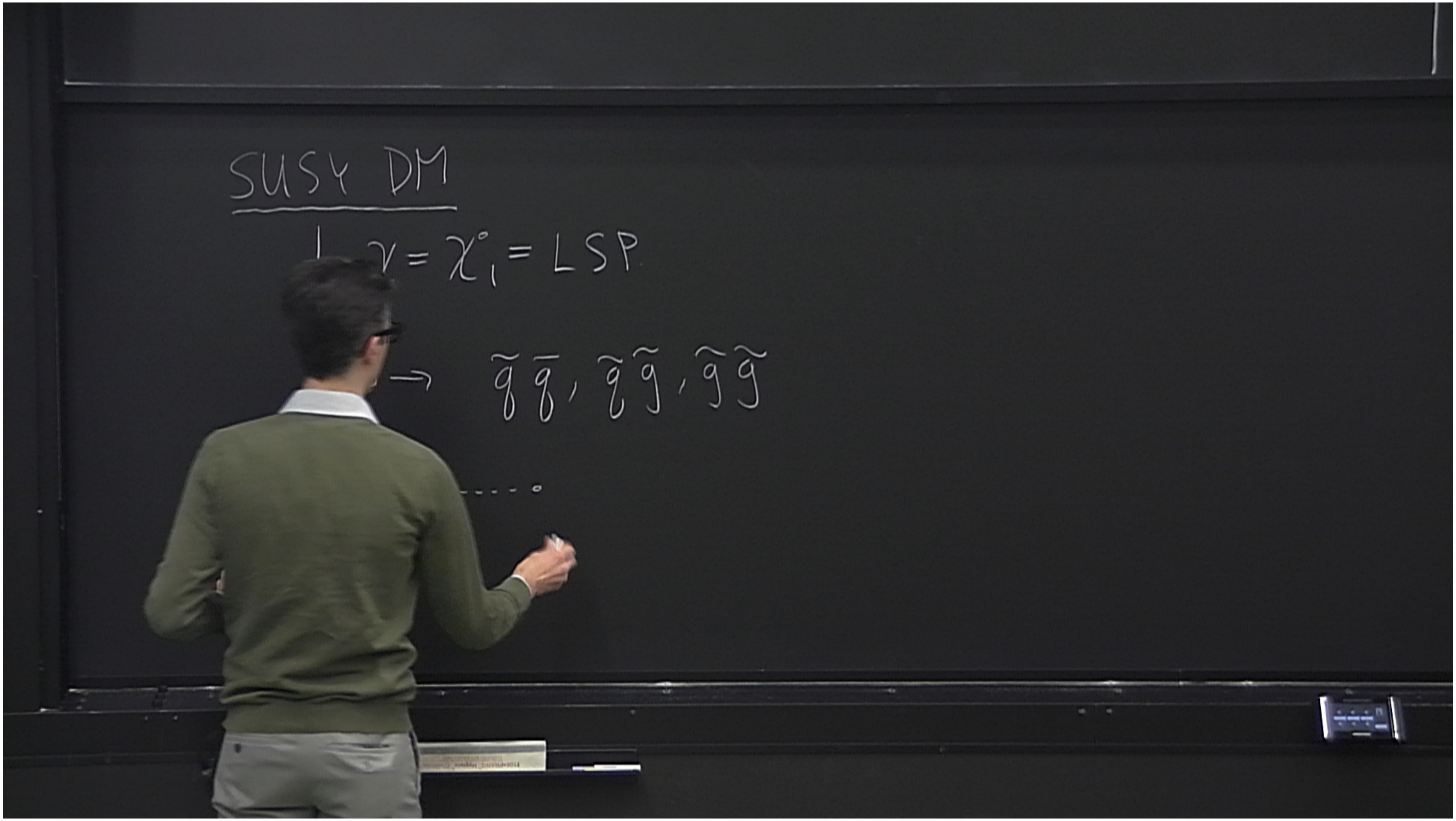

partons = q, q̄, g
8 TeV
.96 TeV
p
p
q
q
Z°
χ

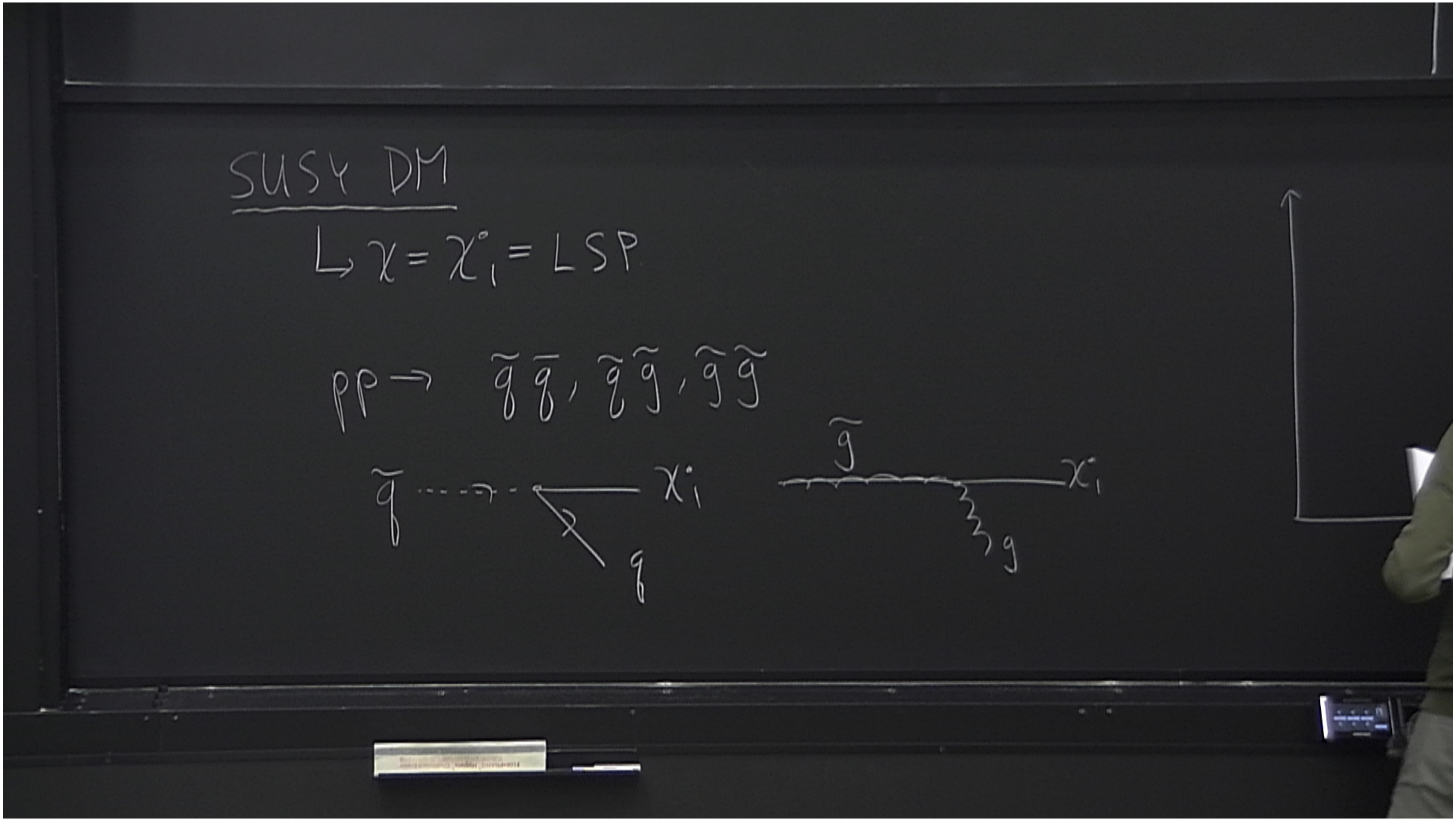


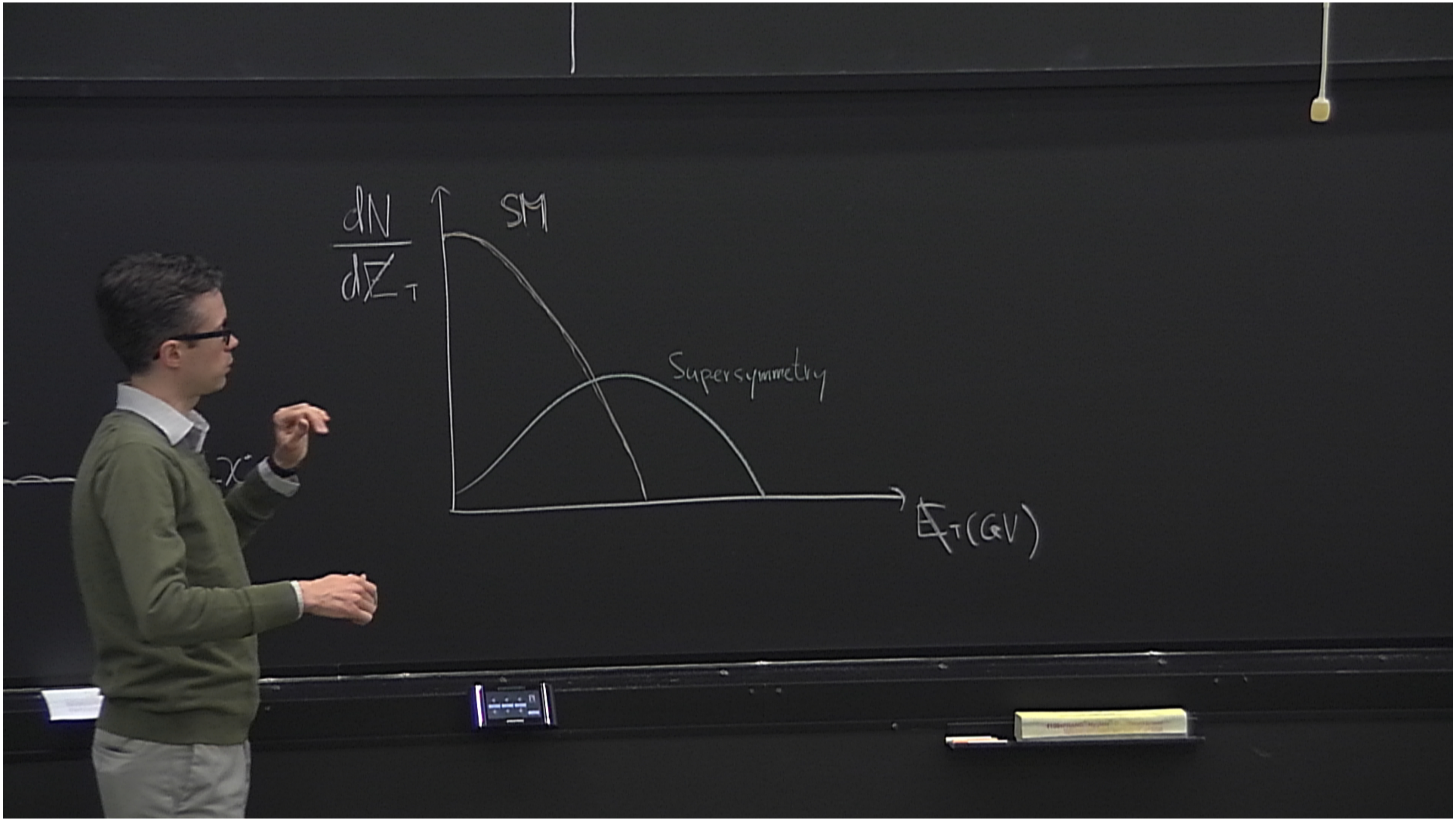
partons = q, q̄, g
8 TeV
.96 TeV
p
p
q
q̄
Z°
χ
χ
transverse plane

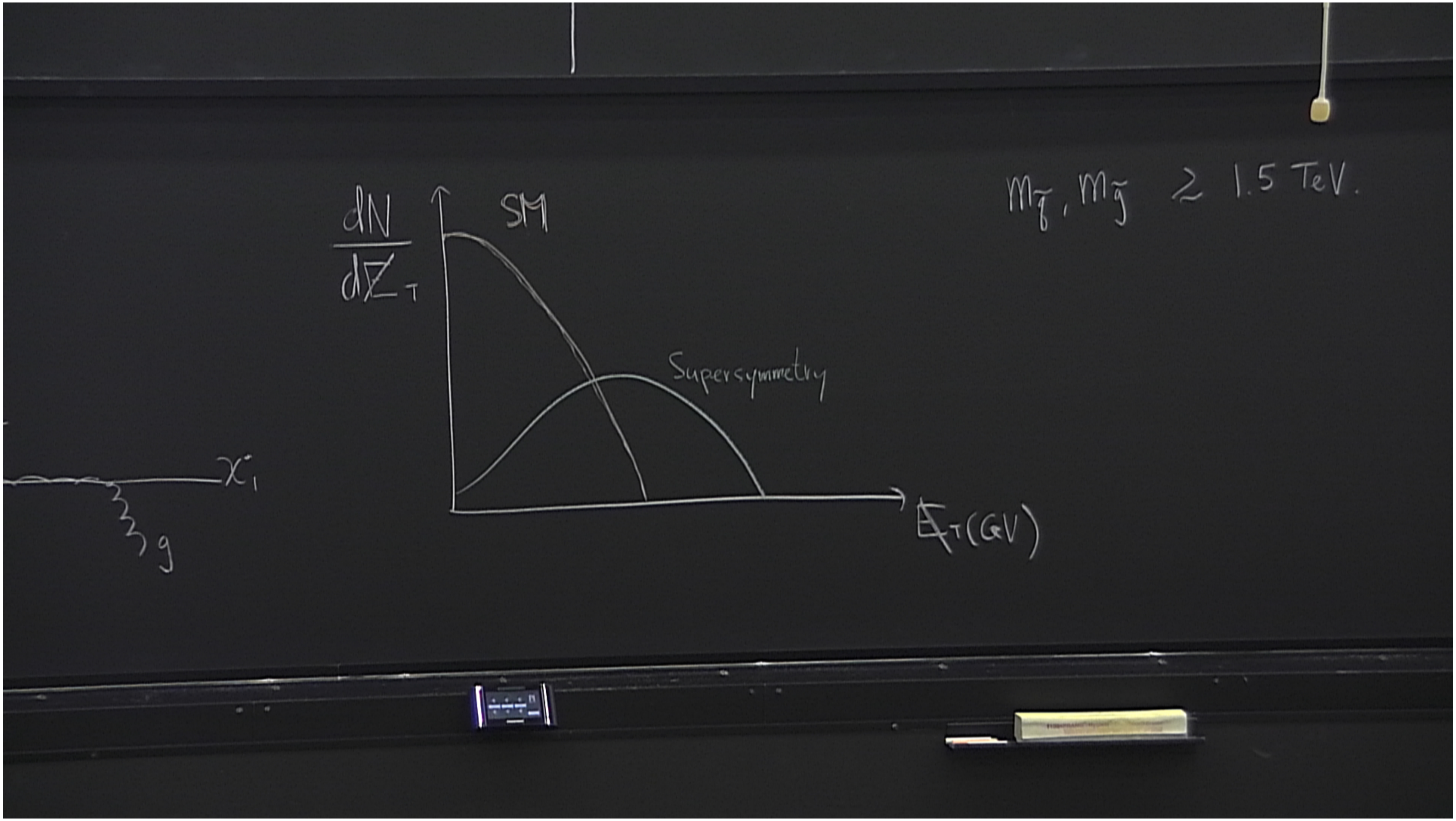

partons = q, q̄, g
8 TeV
.96 TeV
p
p
q
q
Z°
χ
χ
p⃗i
p⃗Ti
transverse plane

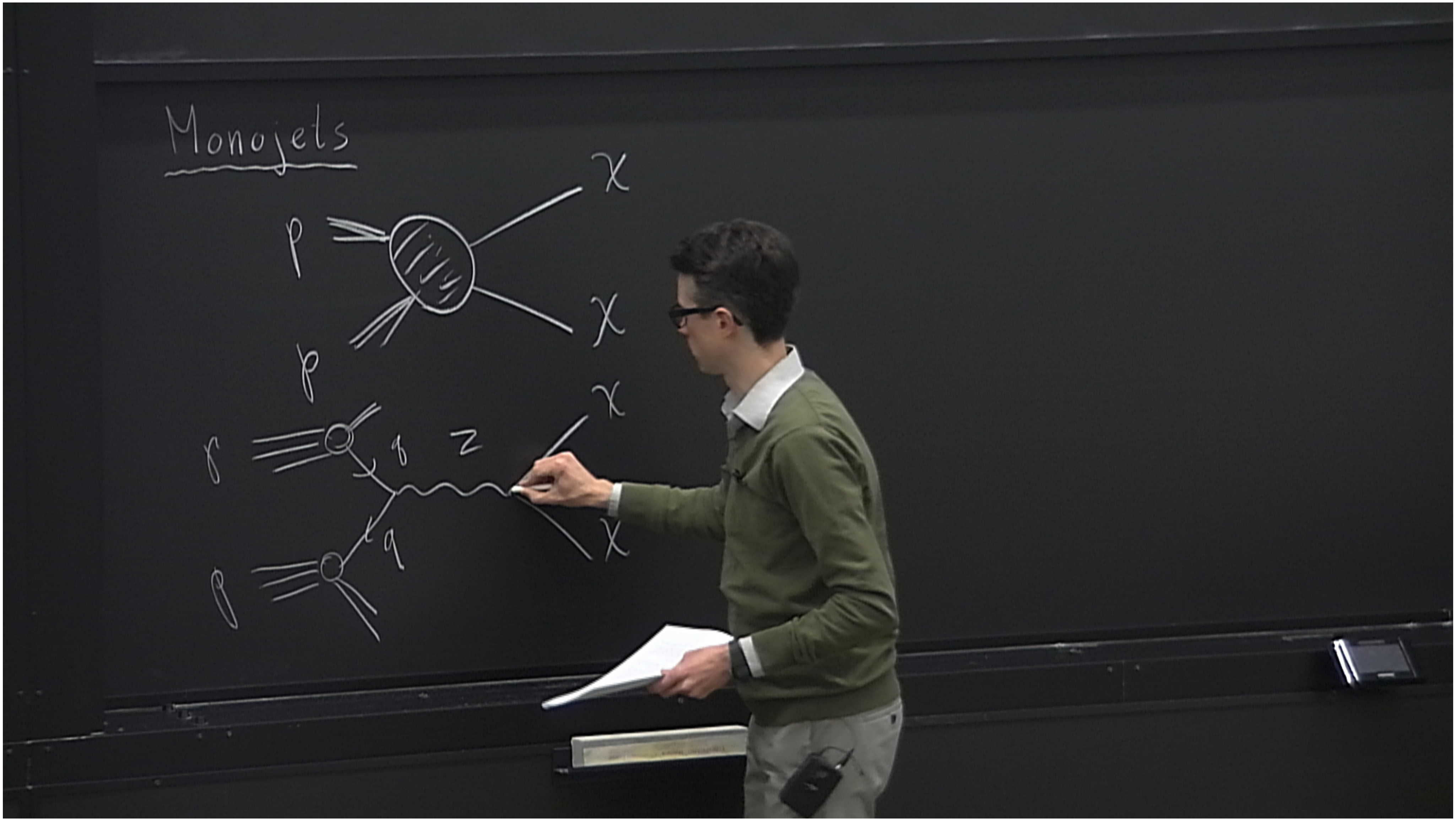

χ carries some $\vec{p}$, E
$\vec{p}_{\chi_1}$
$\vec{p}_{\chi_2}$
$\vec{p}_1$
$\vec{p}_2$
$\vec{\not p}_T = -\sum_{i \in \{vis\}} \vec{p}_{T_i}$
$\not E_T := \| \vec{\not p}_T \|$

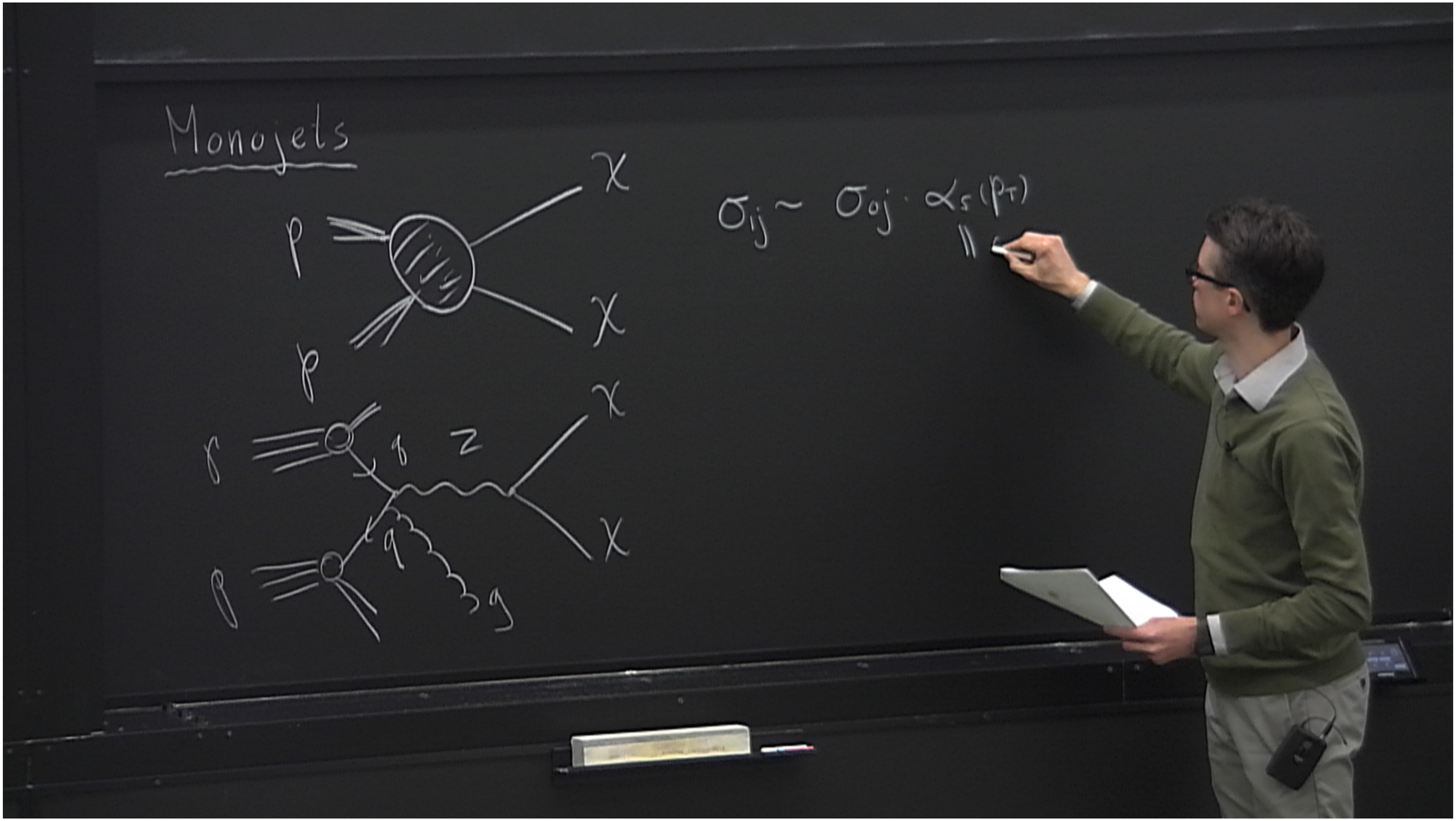

SUSY DM
χ = χ°1 = LSP
→ q̃ q̃̄, q̃ g̃, g̃ g̃

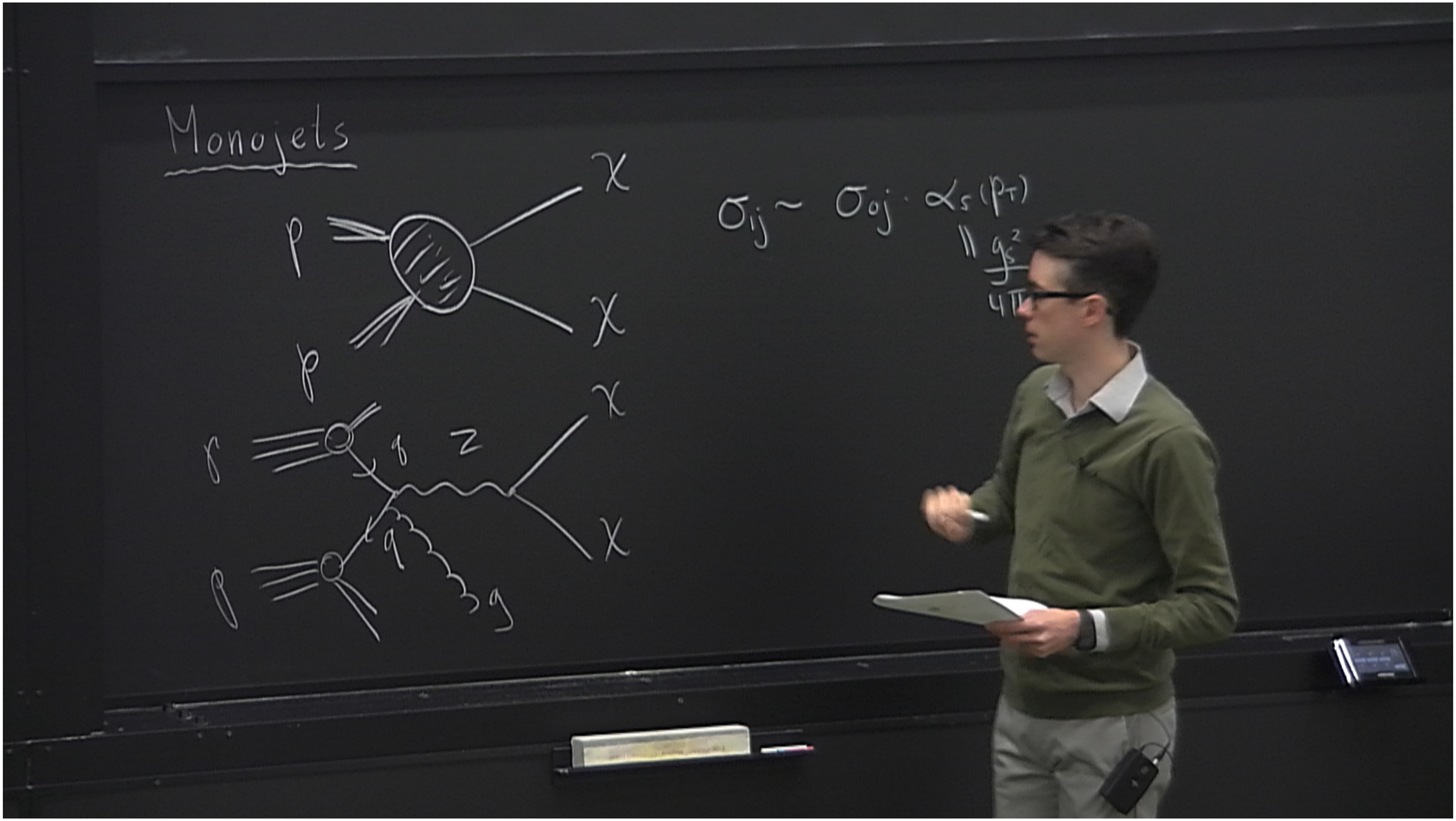

SUSY DM
$\hookrightarrow \chi = \chi_1^0 = LSP$
$pp \to \tilde{q}\bar{\tilde{q}}, \tilde{q}\tilde{g}, \tilde{g}\tilde{g}$
$\tilde{q}$
χ_1^0
q
$\tilde{g}$
χ_1^0
g

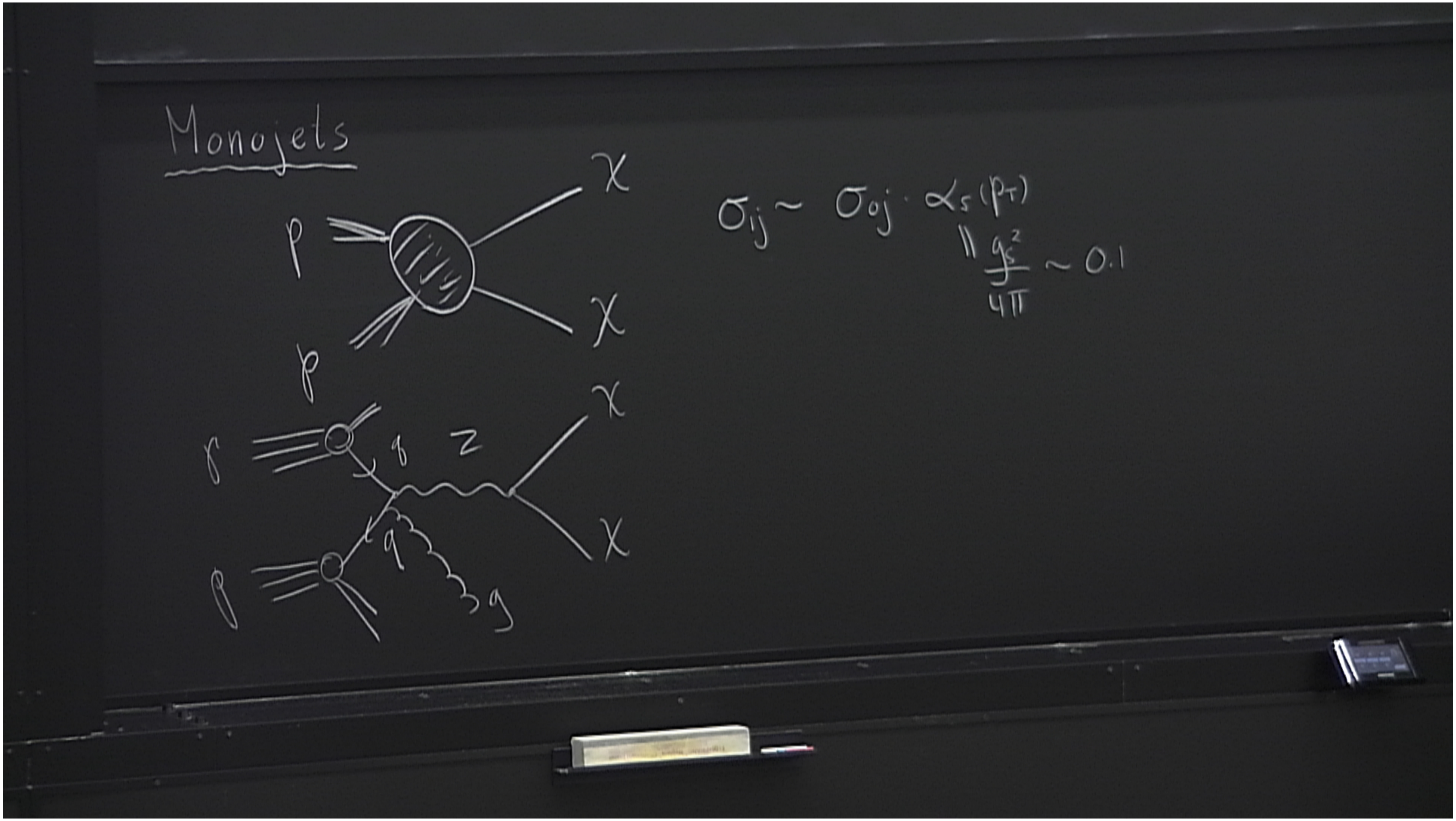

SM
Supersymmetry

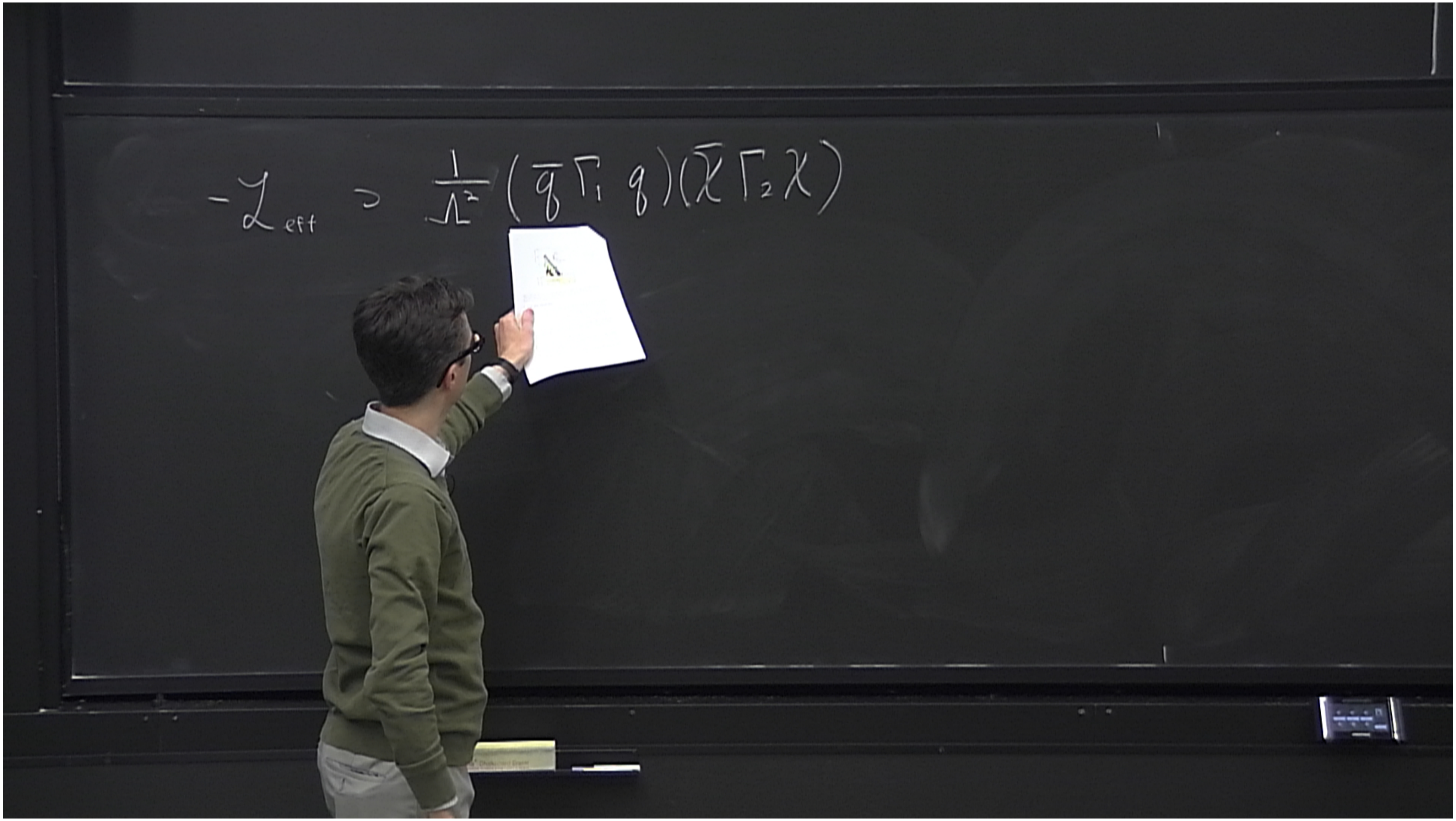

dN/dE̸T
SM
Supersymmetry
E̸T (GeV)
mq̃ , mg̃ ≳ 1.5 TeV.
χ1
g

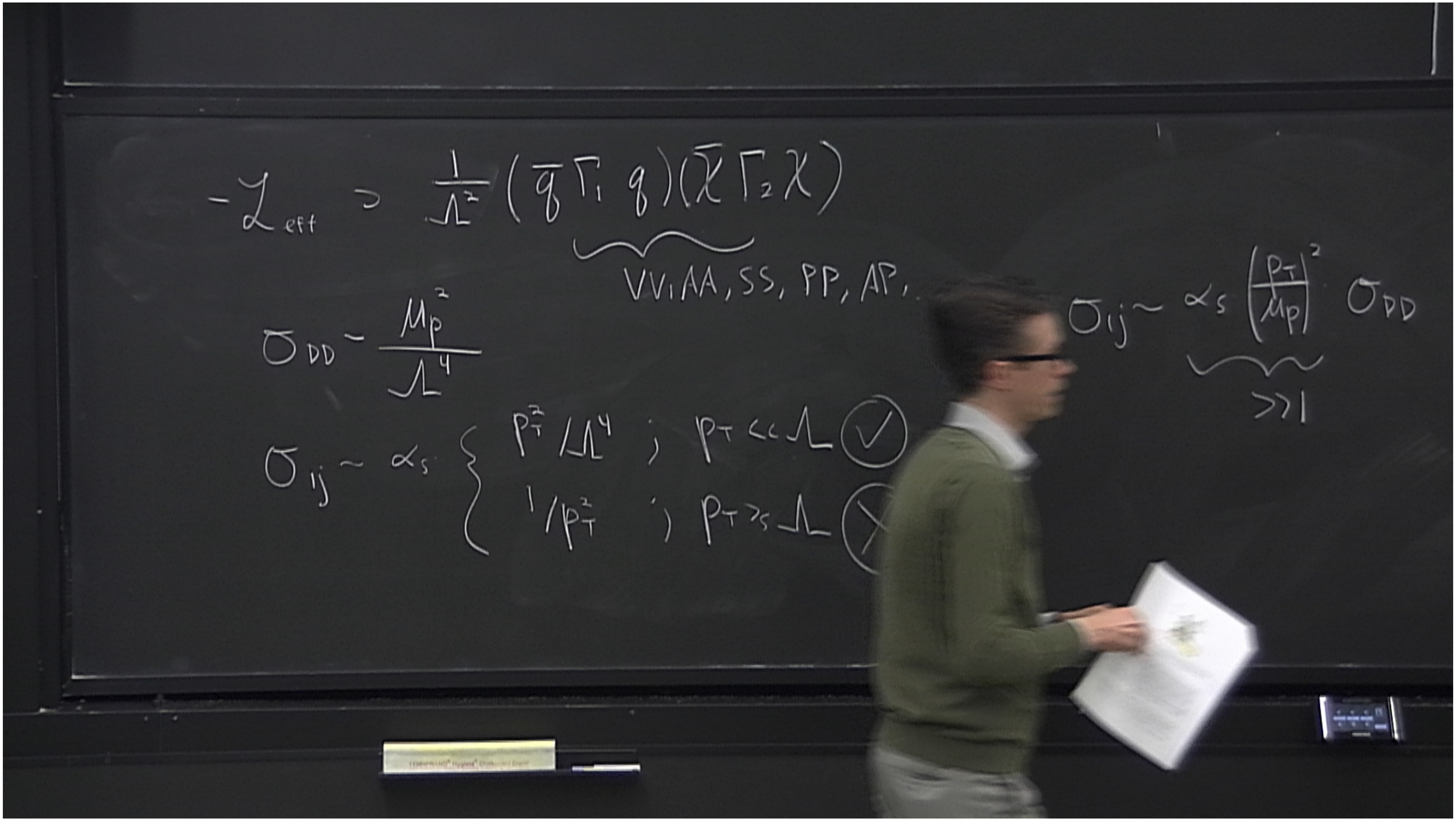

Monojets
p
p
χ
χ
p
p
g
Z
q
χ
χ


Monojets
p
p
χ
χ
$\sigma_{ij} \sim \sigma_{0j} \cdot \alpha_s(p_T)$
p
p
γ Z
χ
χ
q
g


Monojets
p
p
χ
χ
$\sigma_{ij} \sim \sigma_{0j} \cdot \alpha_s(p_T)$
Z
q
g
χ
χ
p
p


Monojets
p
p
χ
χ
σij ~ σ0j · αs(pT)
|| gs²/4π ~ 0.1
p
p
q
Z
q
g
χ
χ


$-\mathcal{L}_{eff} \supset \frac{1}{\Lambda^2}(\bar{q}\,\Gamma_1\, q)(\bar{\chi}\,\Gamma_2\,\chi)$


$-\mathcal{L}_{eff} \supset \frac{1}{\Lambda^2}(\bar{q}\Gamma_1 q)(\bar{\chi}\Gamma_2\chi)$
VV, AA, SS, PP, AP, ...
$\sigma_{DD} \sim \frac{\mu_p^2}{\Lambda^4}$
$\sigma_{ij} \sim \alpha_s \begin{cases} p_T^2/\Lambda^4 \; ; \; p_T \ll \Lambda \\ 1/p_T^2 \; ; \; p_T \gg \Lambda \end{cases}$
$\sigma_{ij} \sim \alpha_s \left(\frac{p_T}{\mu_p}\right)^2 \sigma_{DD}$
$\gg 1$

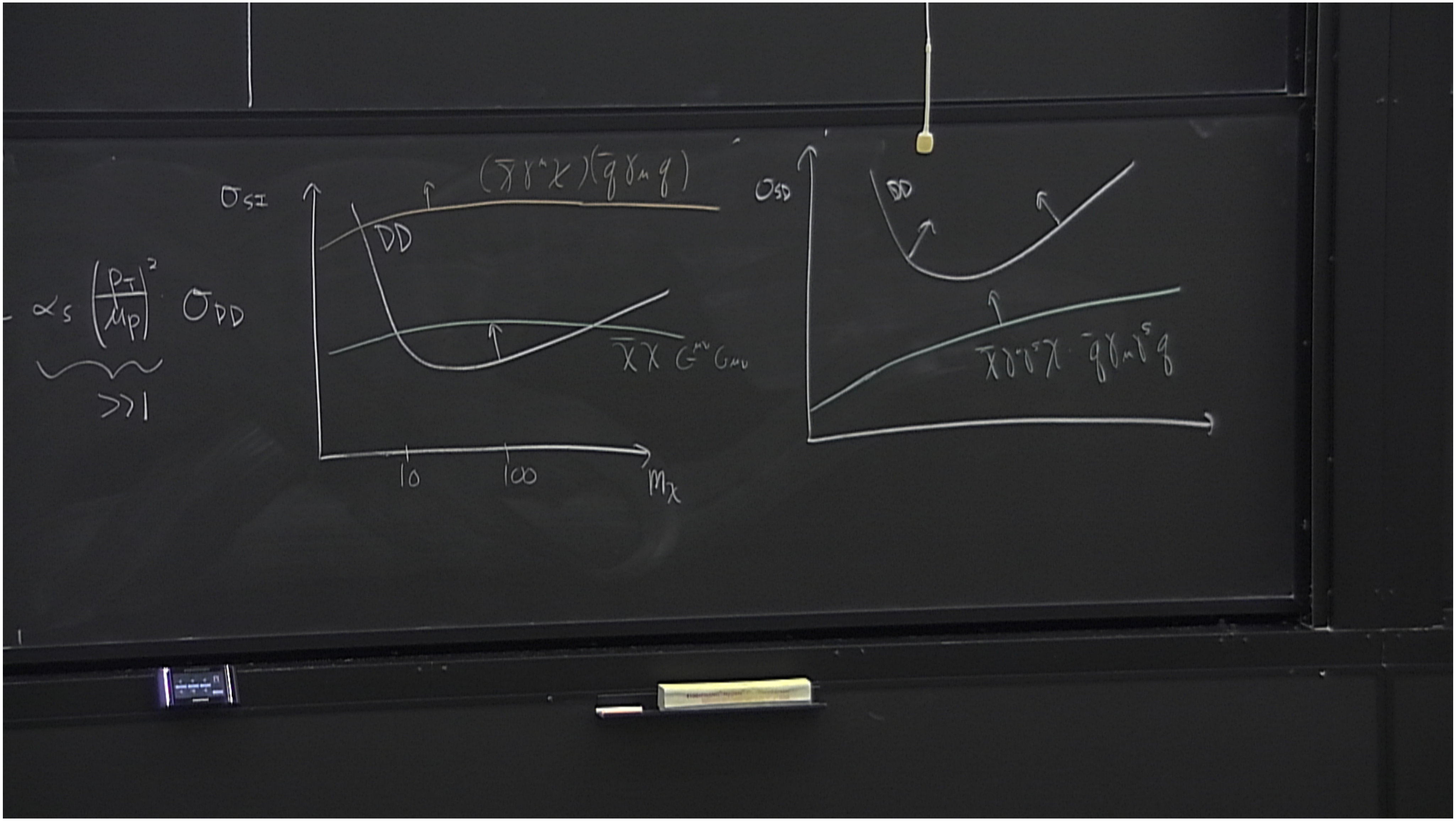
$$-\mathcal{L}_{eff} \supset \frac{1}{\Lambda^2} \underbrace{(\bar{q}\,\Gamma_1\, q)(\bar{\chi}\,\Gamma_2\,\chi)}_{VV,\, AA,\, SS,\, PP,\, AP,\, \ldots}$$

$$\sigma_{SI}$$

$$\sigma_{DD} \sim \frac{\mu_p^2}{\Lambda^4}$$

$$\sigma_{ij} \sim \alpha_s \begin{cases} p_T^2/\Lambda^4 \;;\; p_T \ll \Lambda & \checkmark \\ 1/p_T^2 \;;\; p_T \gg \Lambda & \times \end{cases}$$

$$\sigma_{ij} \sim \alpha_s \underbrace{\left(\frac{p_T}{\mu_p}\right)^2}_{\gg 1} \sigma_{DD}$$


σ_{SI}
$(\bar{\chi}\gamma^{\mu}\chi)(\bar{q}\gamma_{\mu}q)$
DD
$\alpha_s \left(\frac{p_T}{m_p}\right)^2 \sigma_{DD}$
$\gg 1$
$\bar{\chi}\chi\, G^{\mu\nu}G_{\mu\nu}$
10
100
m_χ
σ_{SD}
DD
$\bar{\chi}\gamma^{\mu}\gamma^{5}\chi \cdot \bar{q}\gamma_{\mu}\gamma^{5}q$