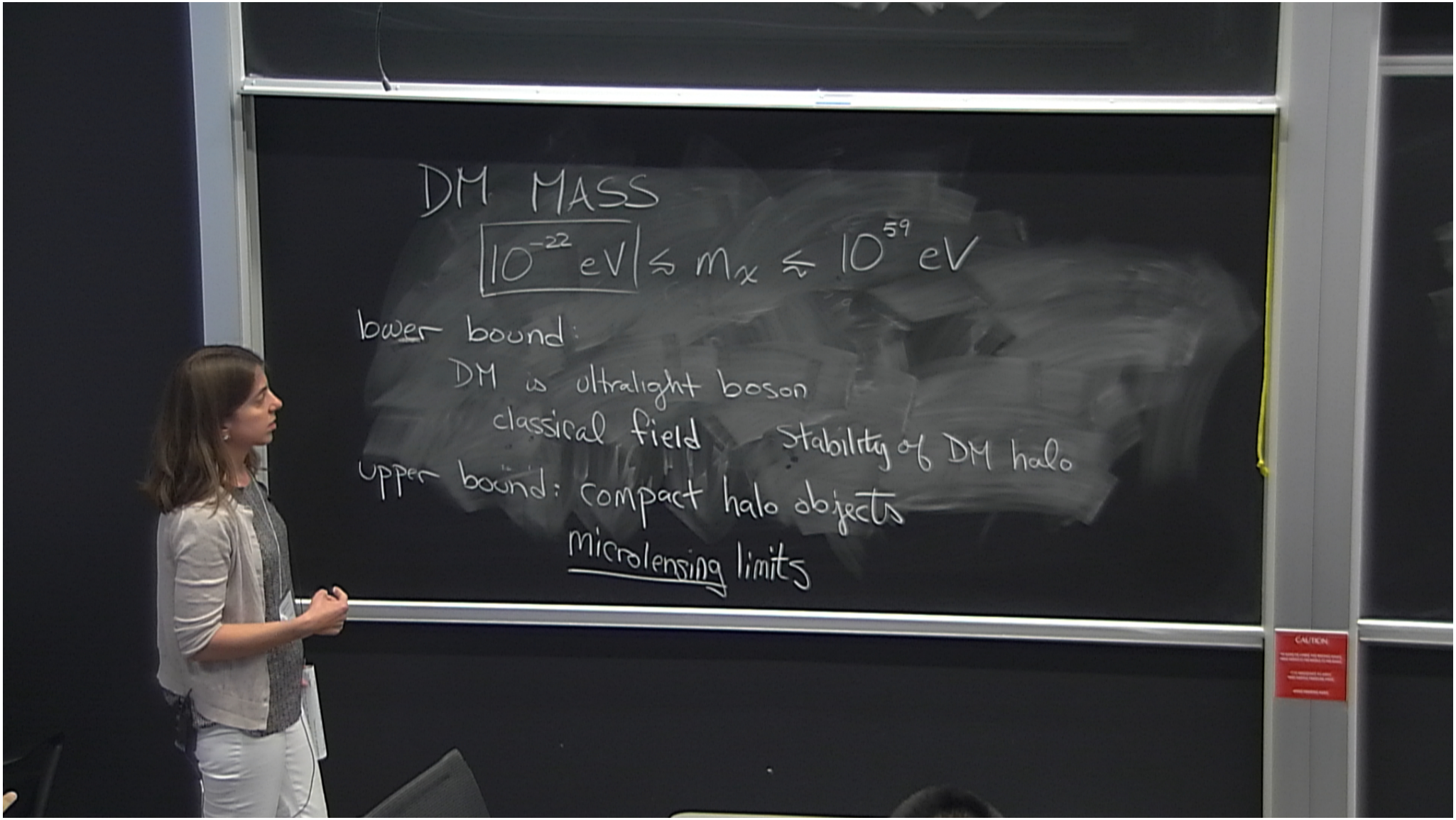
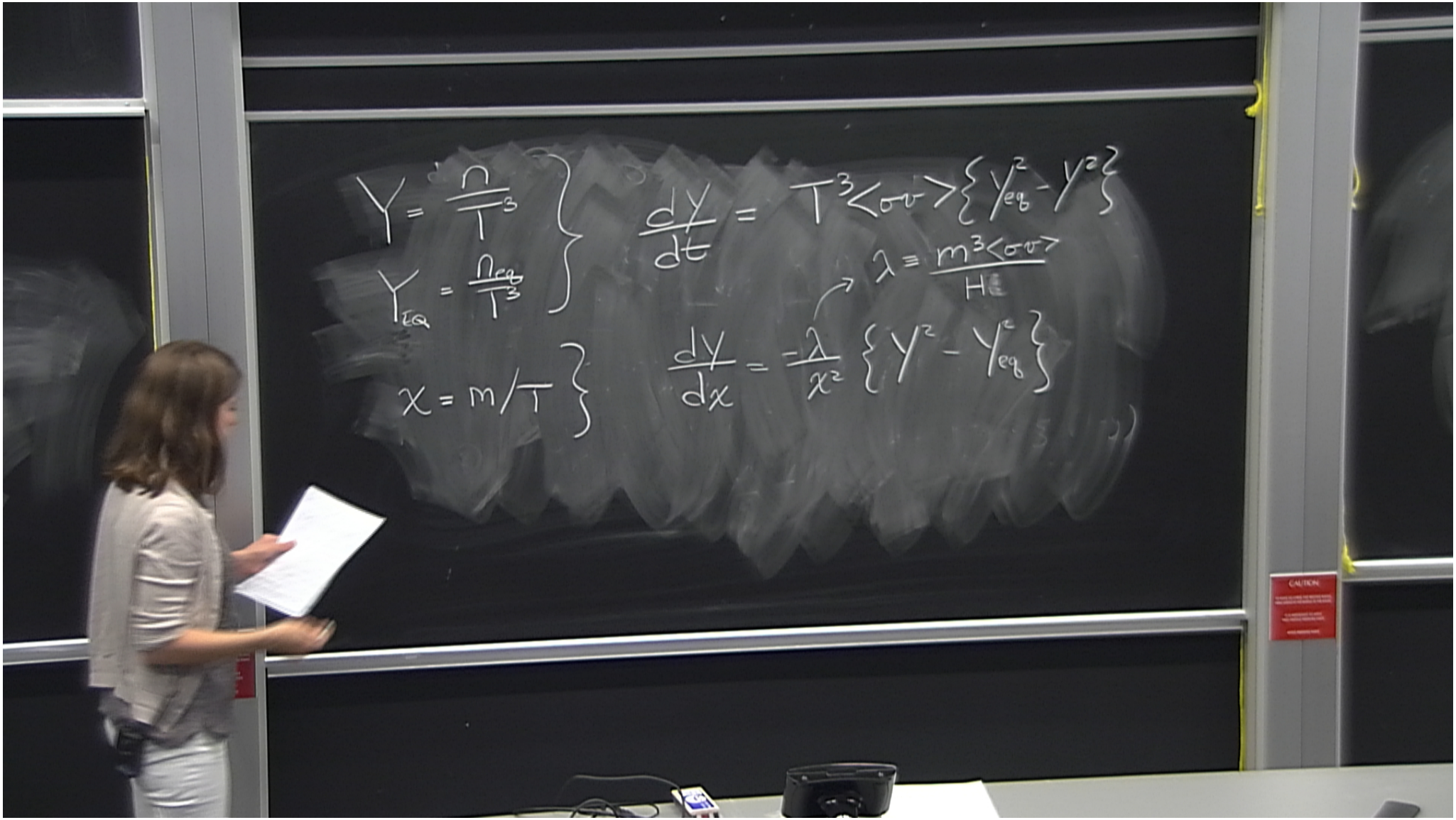
Title: Astroparticle Physics â€“ Theory: Dark Matter Distribution in MW

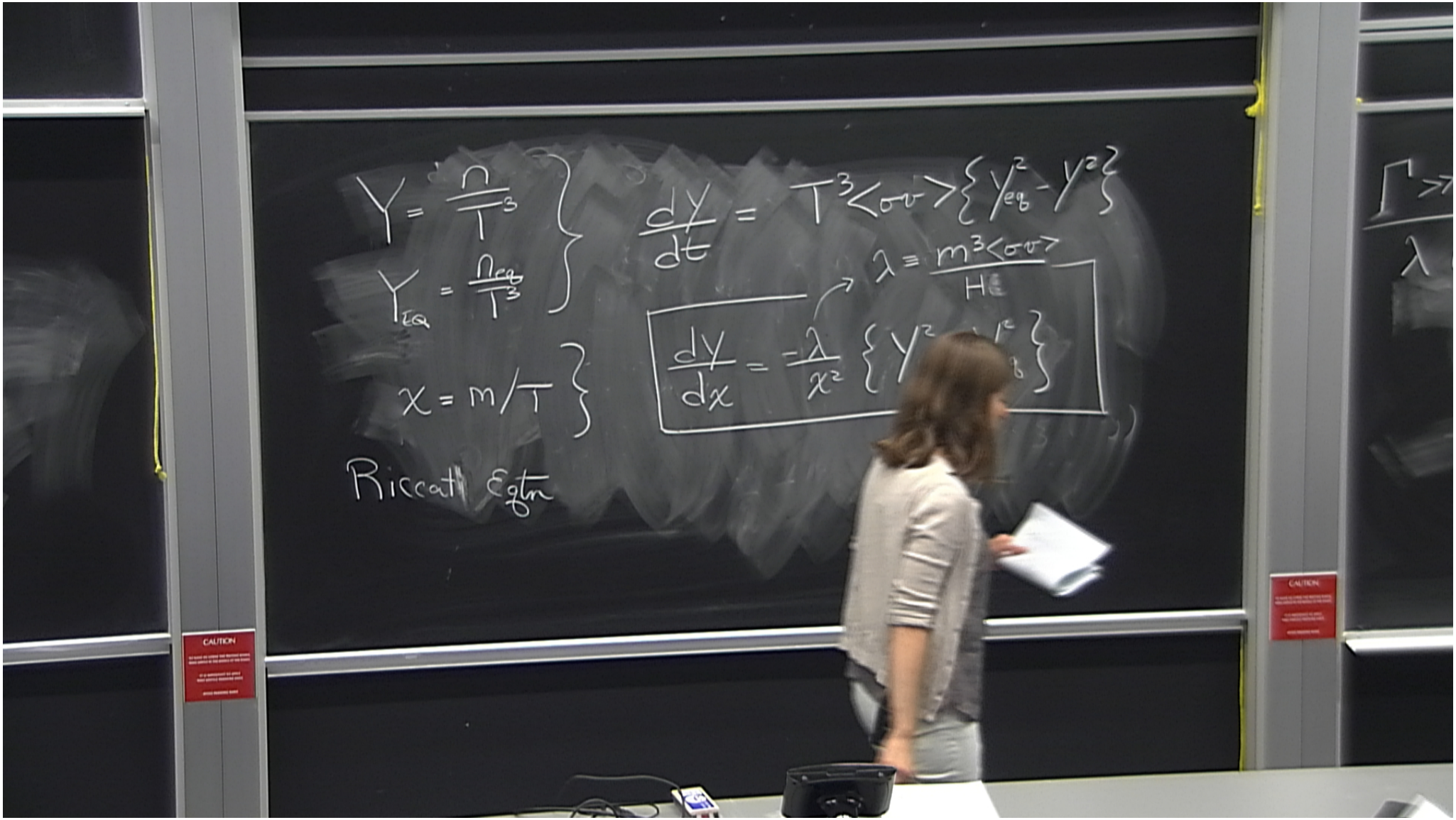
Date: Jul 06, 2015 03:45 PM

URL: http://pirsa.org/15070016

Abstract:


DM MASS
10^{-22} eV $\lesssim m_\chi \lesssim 10^{59}$ eV
lower bound:
DM is ultralight boson
classical field
stability of DM halo
upper bound: compact halo objects
microlensing limits


$Y = \frac{n}{T^3}$
$Y_{EQ} = \frac{n_{eq}}{T^3}$
$x = m/T$
$\frac{dY}{dt} = T^3 \langle \sigma v \rangle \{ Y_{eq}^2 - Y^2 \}$
$\lambda \equiv \frac{m^3 \langle \sigma v \rangle}{H}$
$\frac{dY}{dx} = -\frac{\lambda}{x^2} \{ Y^2 - Y_{eq}^2 \}$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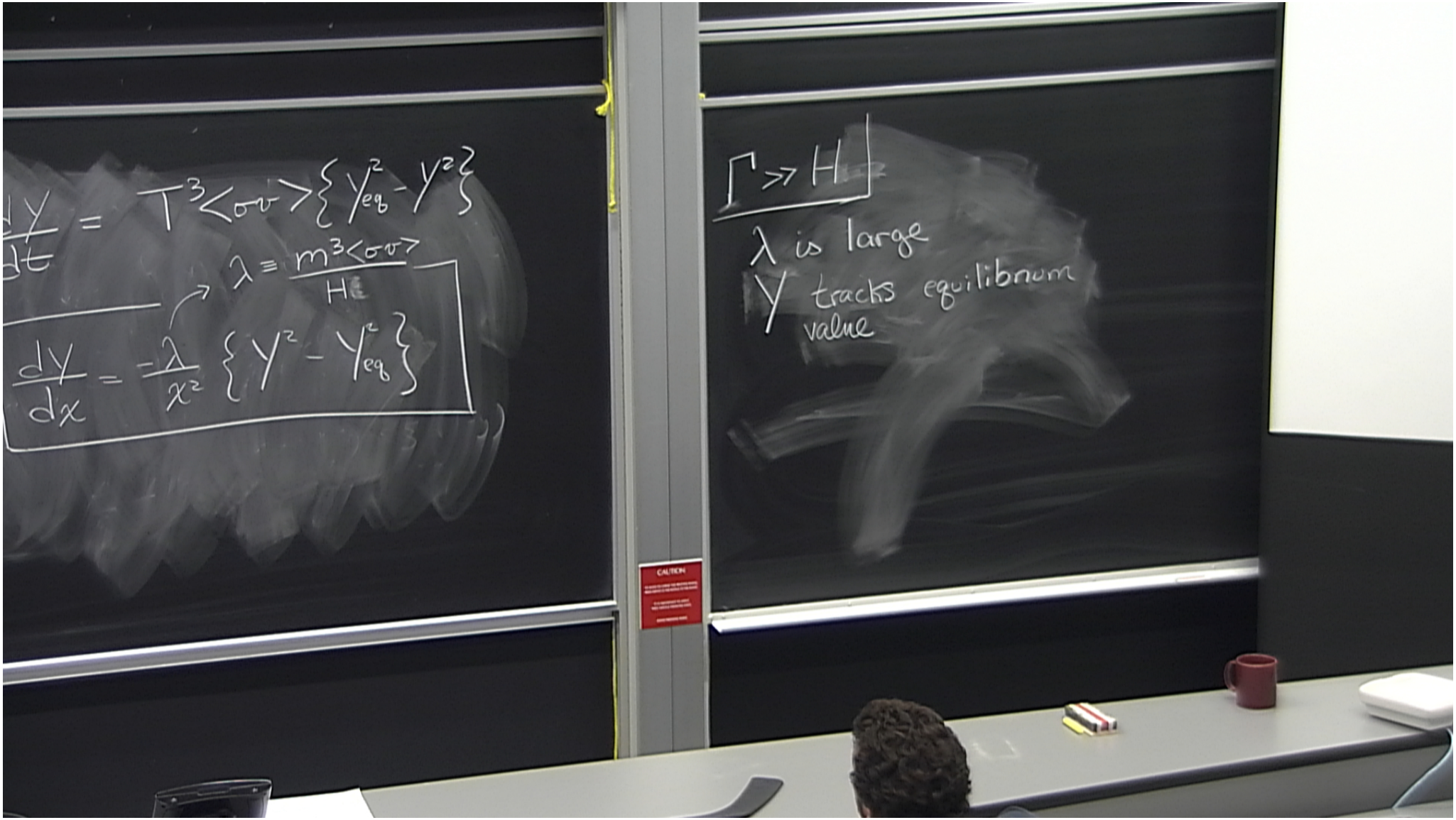
Riccati Eqtn
CAUTION
CAUTION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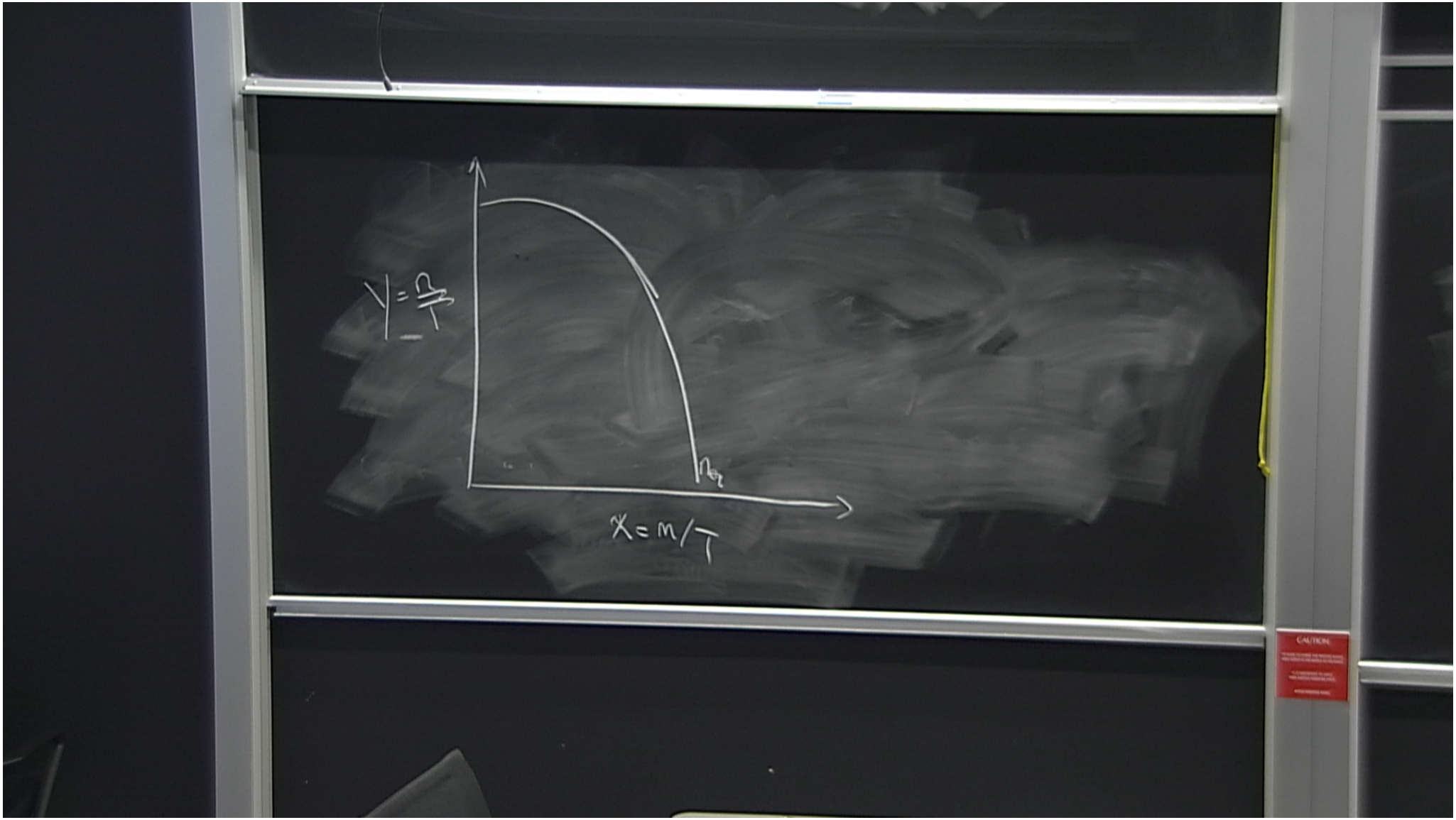
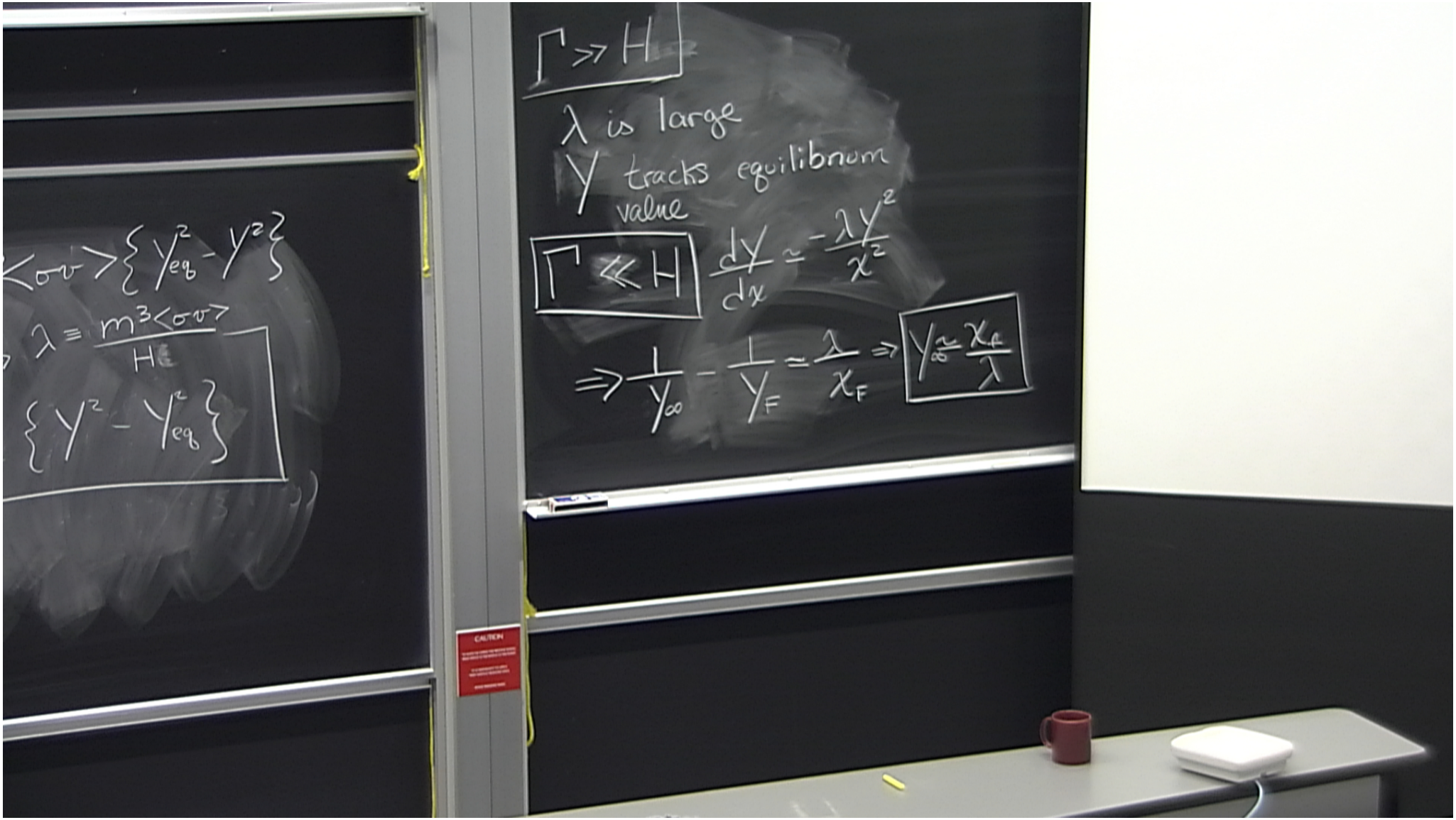
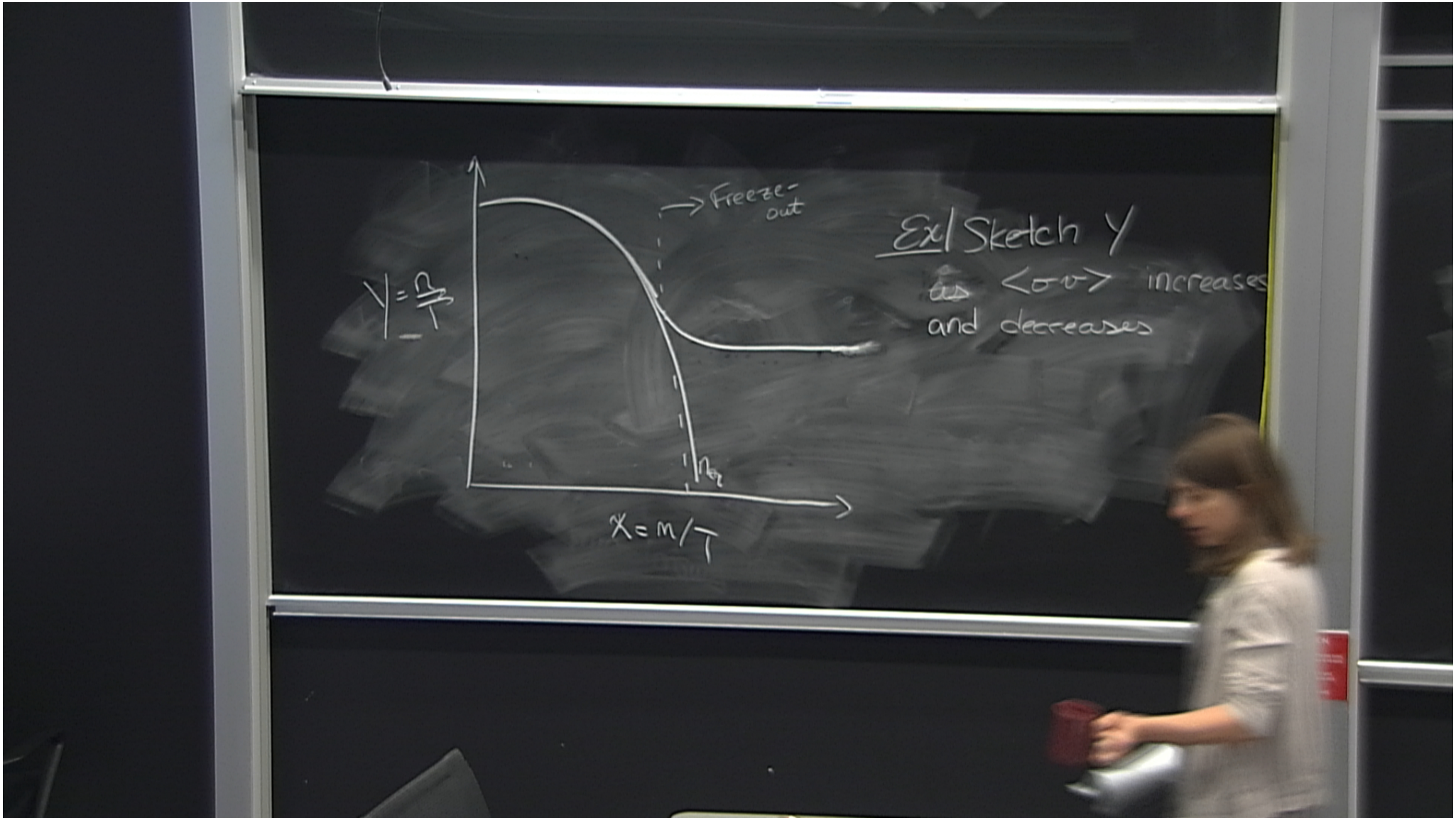
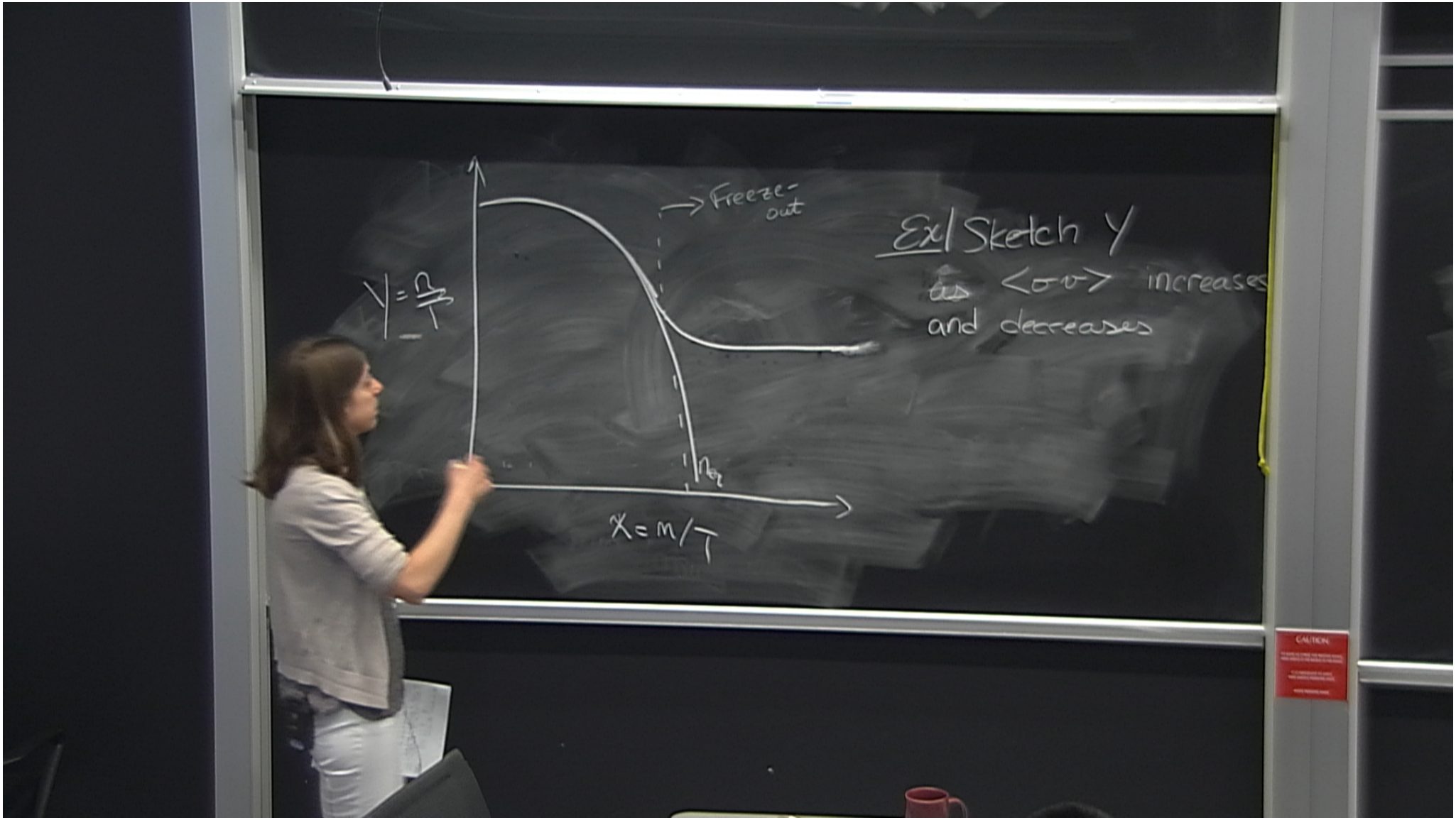
$\Gamma \gg H$
λ is large
Y tracks equilibrium value
CAUTION


$\chi = m/T$


$\Gamma \gg H$
λ is large
Y tracks equilibrium value
$\Gamma \ll H$
$\frac{dY}{dx} \simeq -\frac{\lambda Y^2}{x^2}$
$\Rightarrow \frac{1}{Y_\infty} - \frac{1}{Y_F} \simeq \frac{\lambda}{x_F} \Rightarrow Y_\infty \simeq \frac{x_F}{\lambda}$
$\lambda = \frac{m^3 \langle \sigma v \rangle}{H}$
$\{Y^2 - Y_{eq}^2\}$
$\langle \sigma v \rangle \{Y_{eq}^2 - Y^2\}$
CAUTION


Freeze-out
Ex/ Sketch Y
as <σv> increases
and decreases
Y = n/T
x = m/T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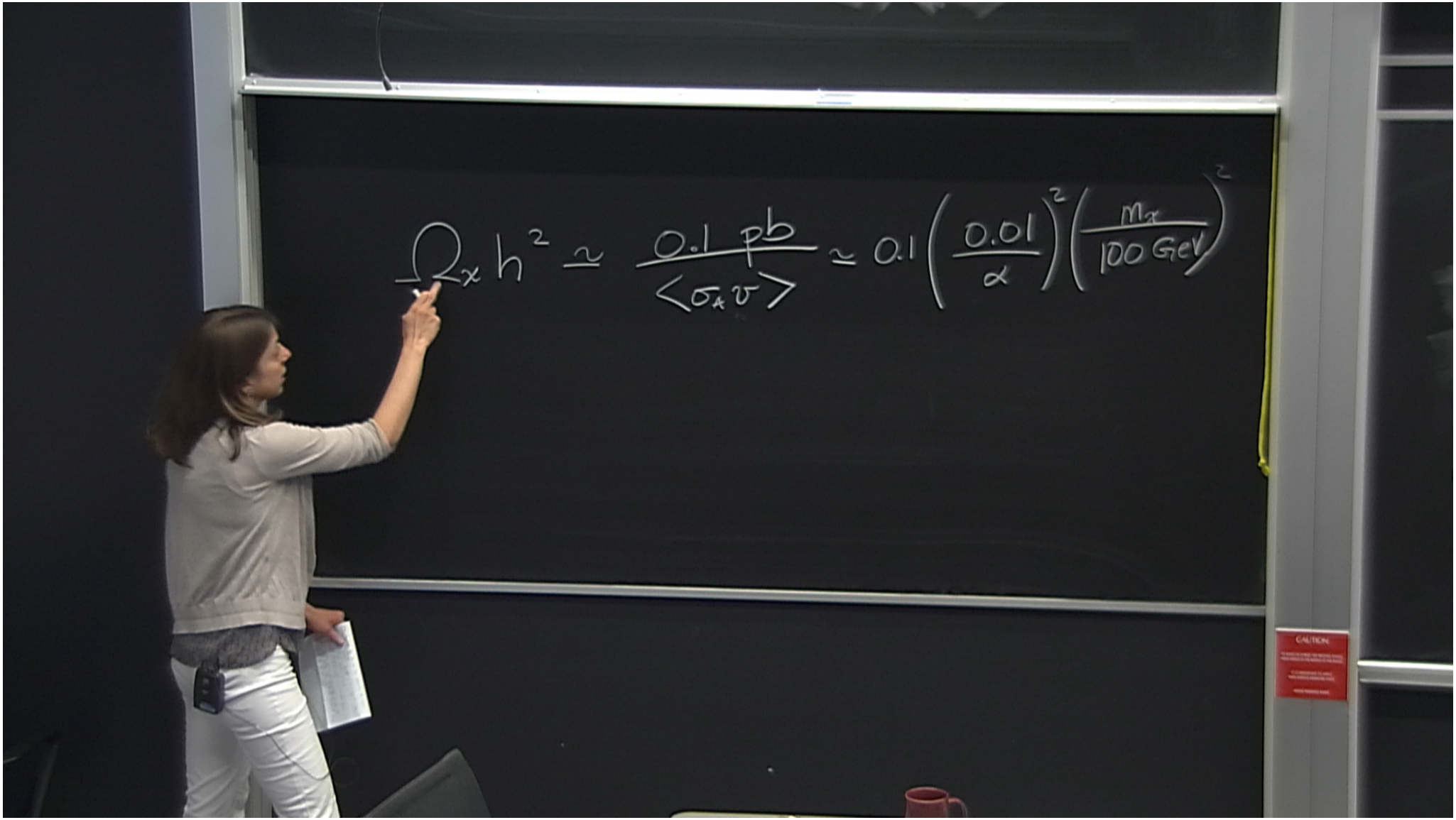
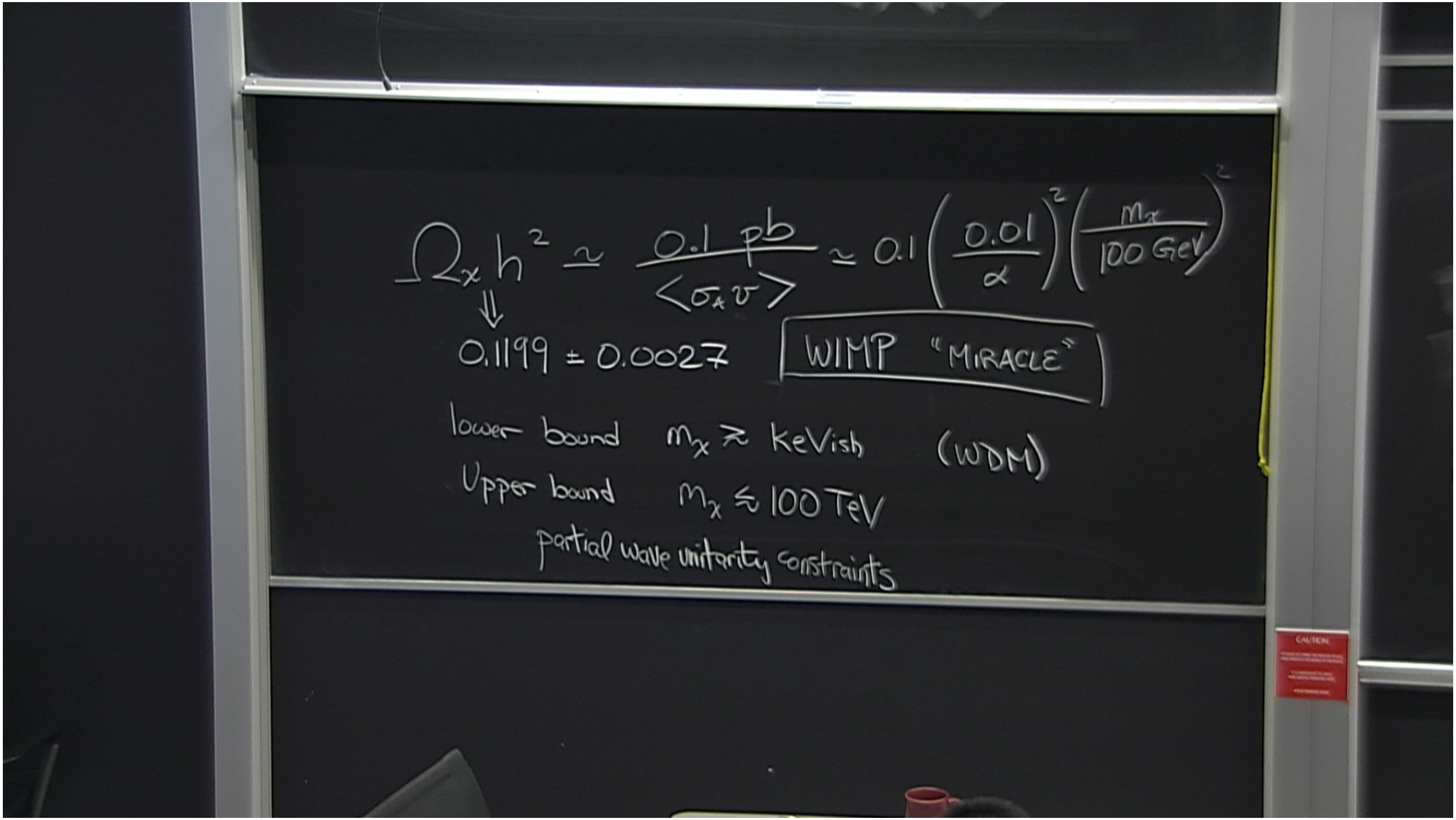
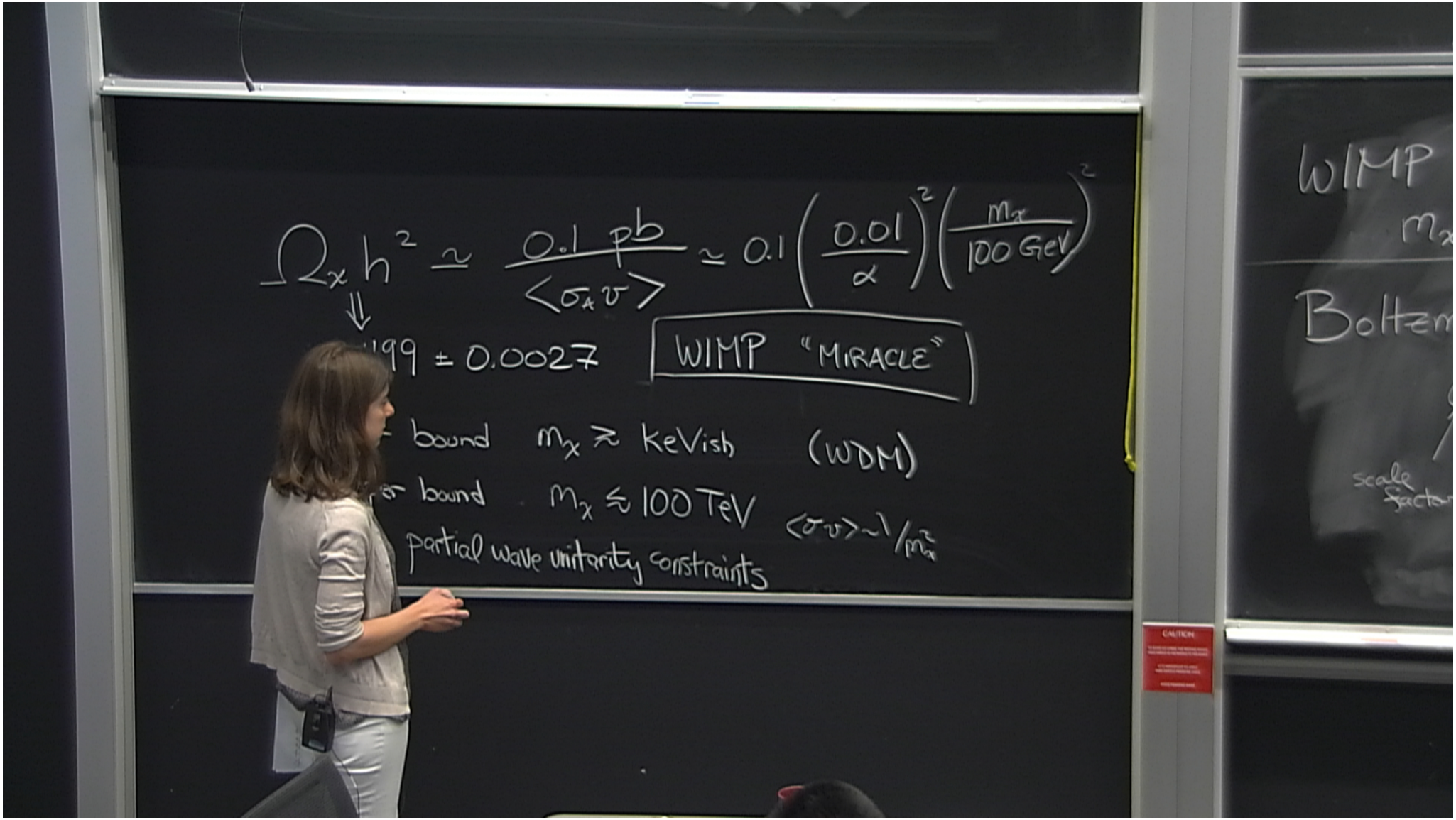

$\Omega_x h^2 \simeq \frac{0.1\ \text{pb}}{\langle \sigma_A v \rangle} \simeq 0.1 \left(\frac{0.01}{\alpha}\right)^2 \left(\frac{m_x}{100\ \text{GeV}}\right)^2$
CAUTION


$\Omega_\chi h^2 \simeq \frac{0.1\ \text{pb}}{\langle \sigma_* v \rangle} \simeq 0.1 \left(\frac{0.01}{\alpha}\right)^2 \left(\frac{m_\chi}{100\ \text{GeV}}\right)^2$
$\Downarrow$
0.1199 ± 0.0027
WIMP "MIRACLE"
lower bound $m_\chi \gtrsim$ keVish (WDM)
Upper bound $m_\chi \lesssim 100$ TeV
partial wave unitarity constraints
CAUTION


Where we've been:
Next: DM Models
WIMP "MIRACLE"
Boltzmann Eqtn
WIMP "MIRACLE"
(WDM)
TeV
Γ >> H
λ is large
Y tracks equilibrium value
Γ << H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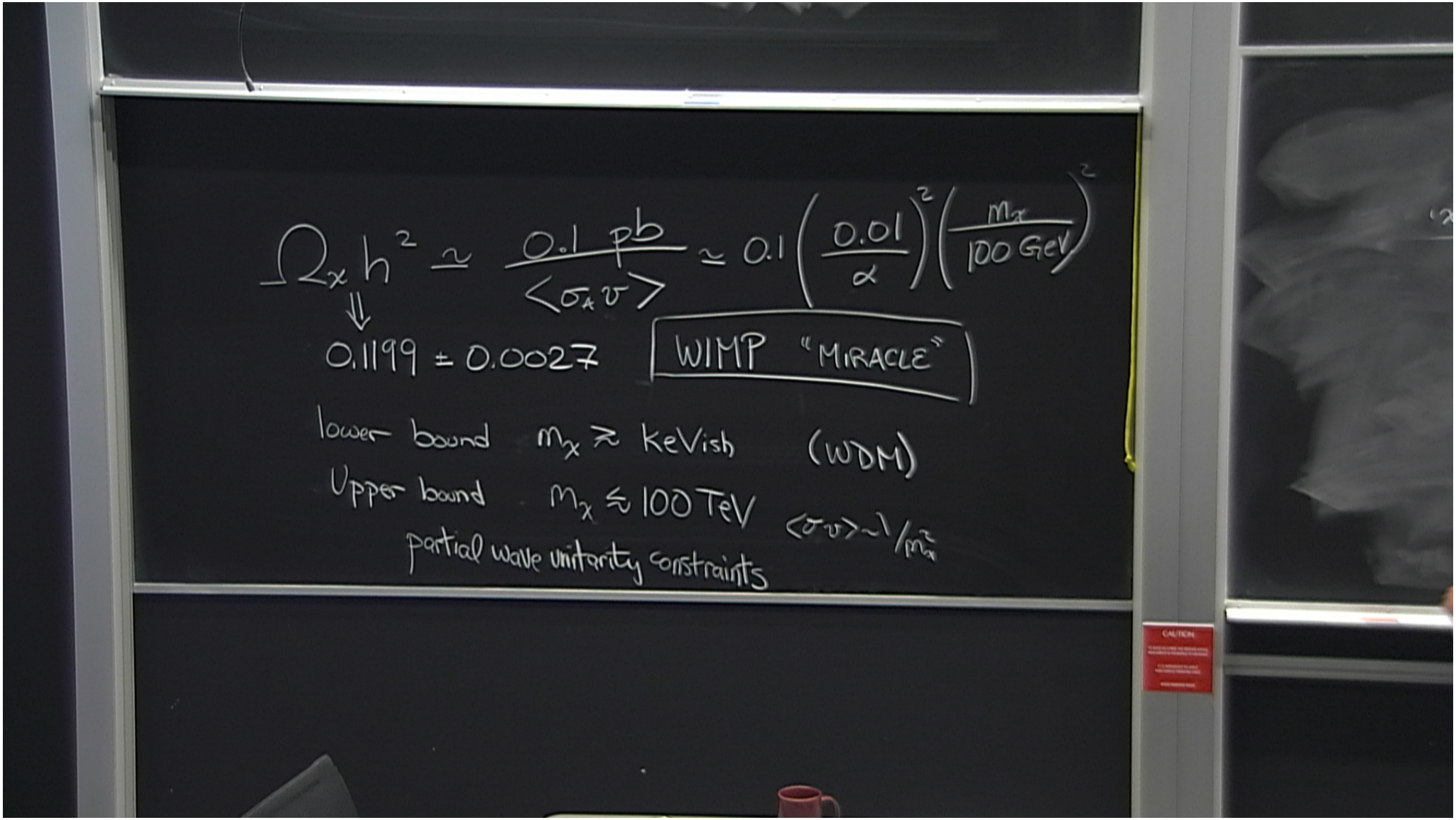
WIMP "MIRACLE"
bound $m_\chi \gtrsim$ keVish (WDM)
bound $m_\chi \lesssim 100$ TeV $\langle \sigma v \rangle \sim 1/m_\chi^2$
partial wave unitarity constraints
WIMP
Bolt
scale factor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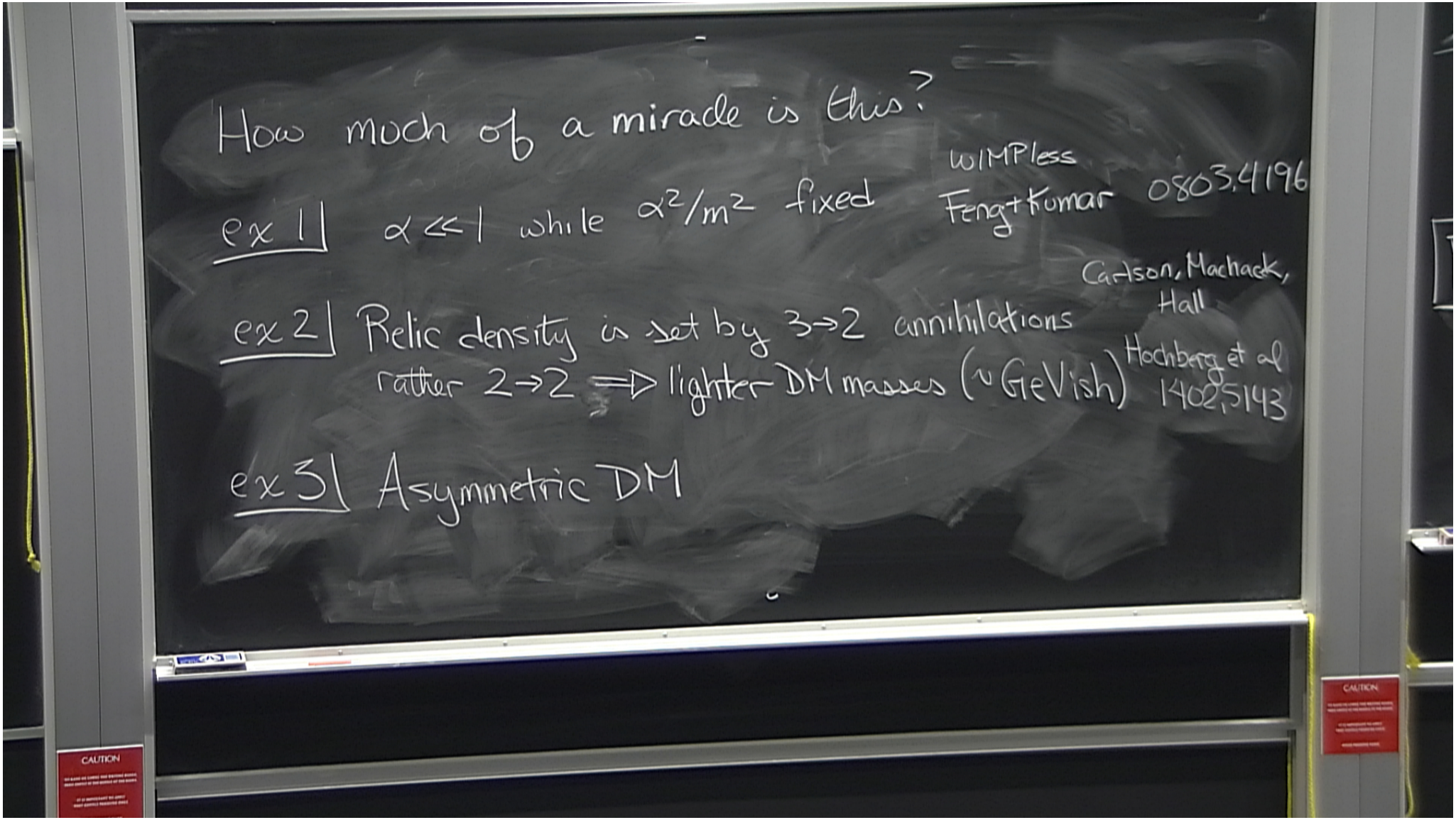
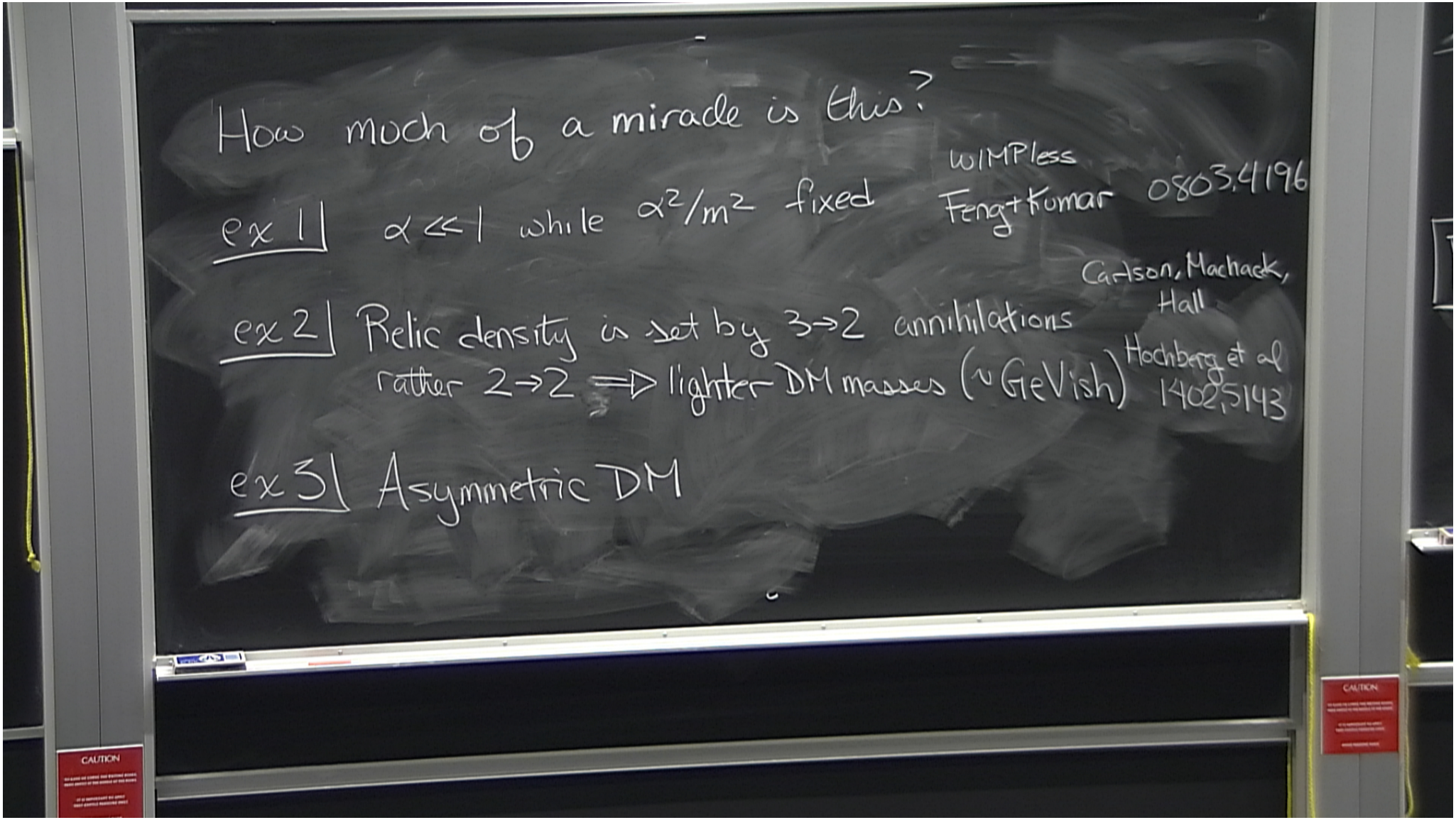

How much of a miracle is this?
ex 1| $\alpha \ll 1$ while α^2/m^2 fixed
WIMPless
Feng+Kumar 0803.4196
ex 2| Relic density is set by 3→2 annihilations
Carlson, Machacek, Hall
rather 2→2 ⇒ lighter DM masses (~GeVish)
Hochberg et al 1402.5143
ex 3| Asymmetric DM
CAUTION
CAUTION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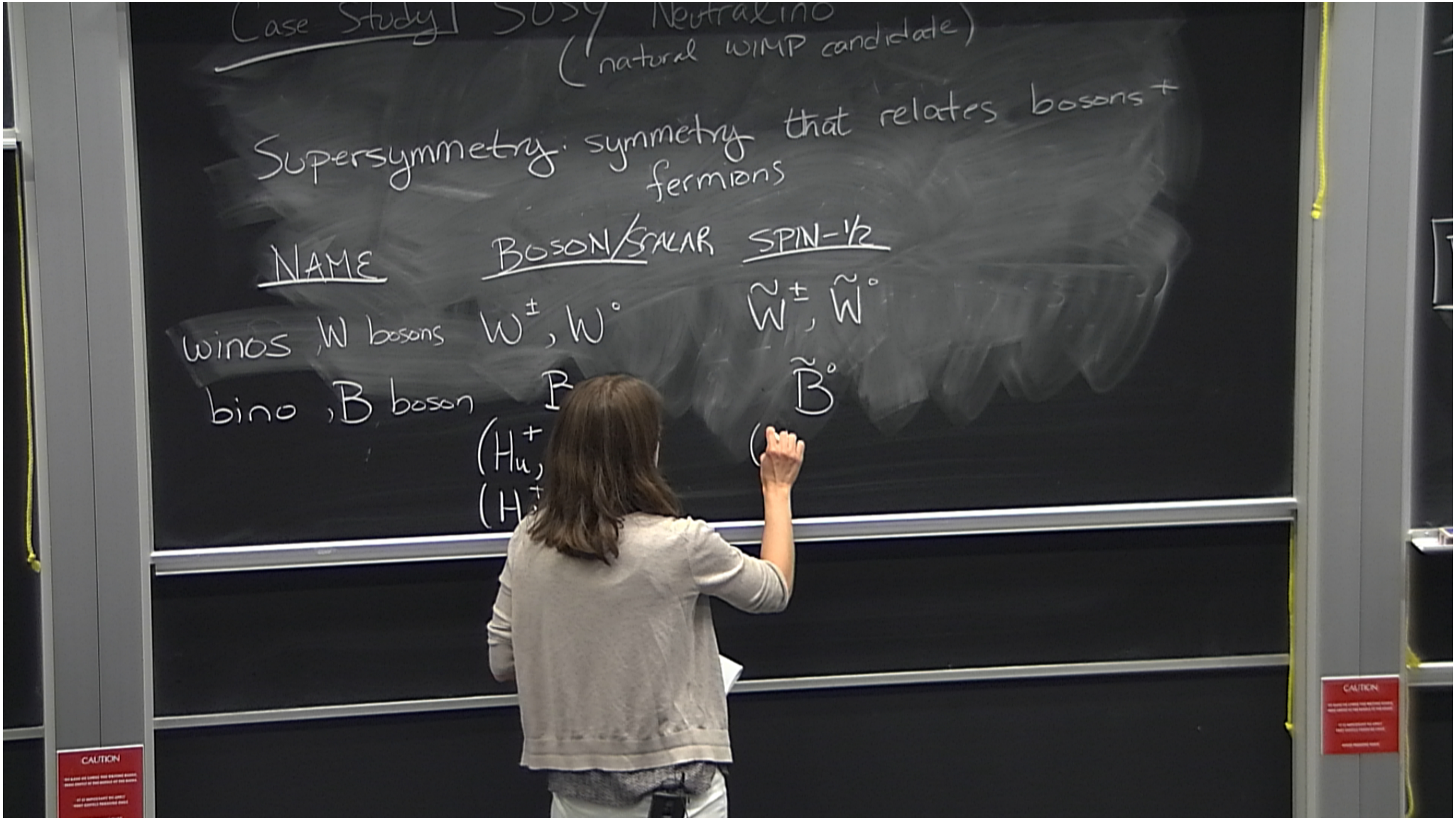
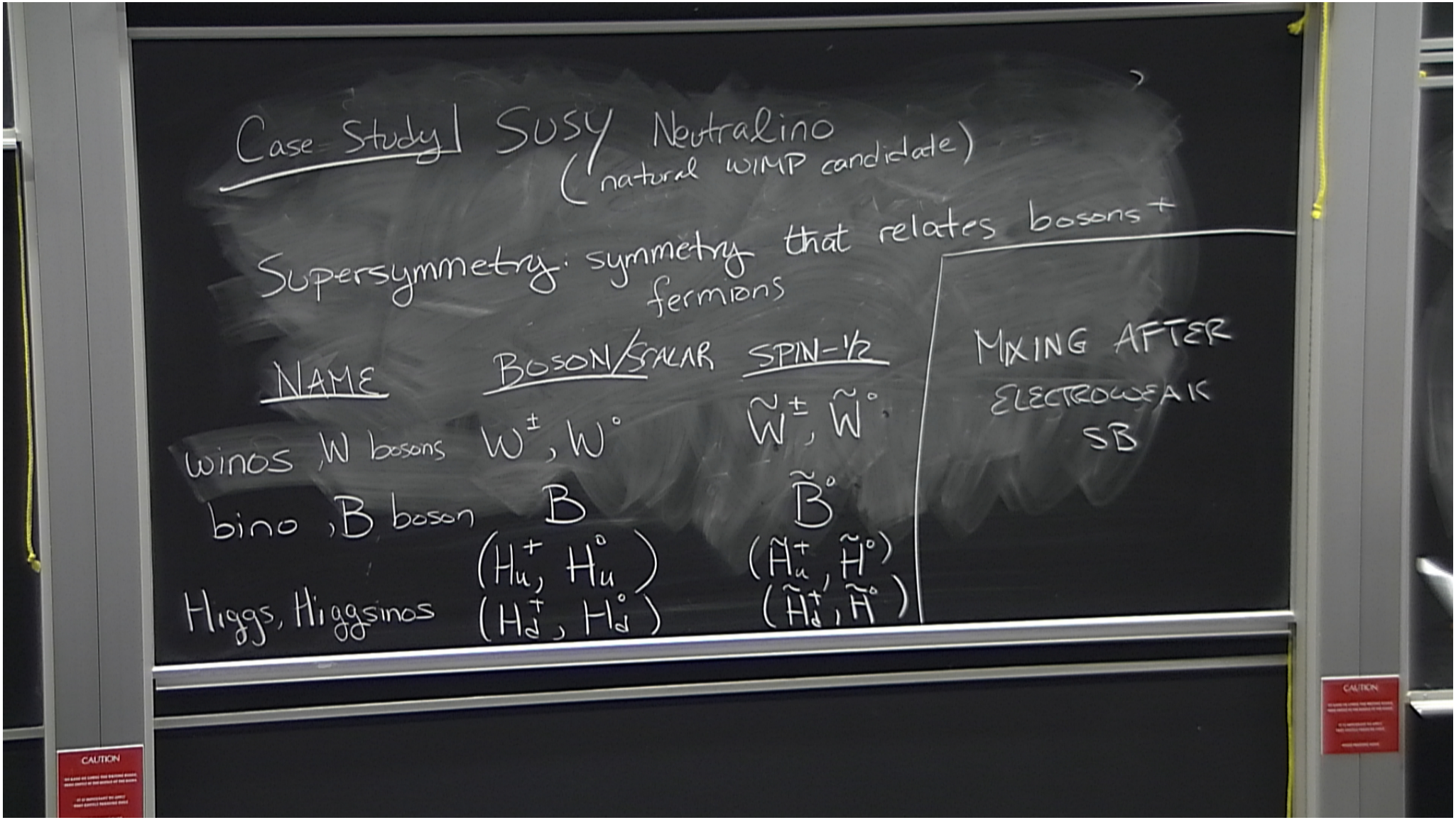
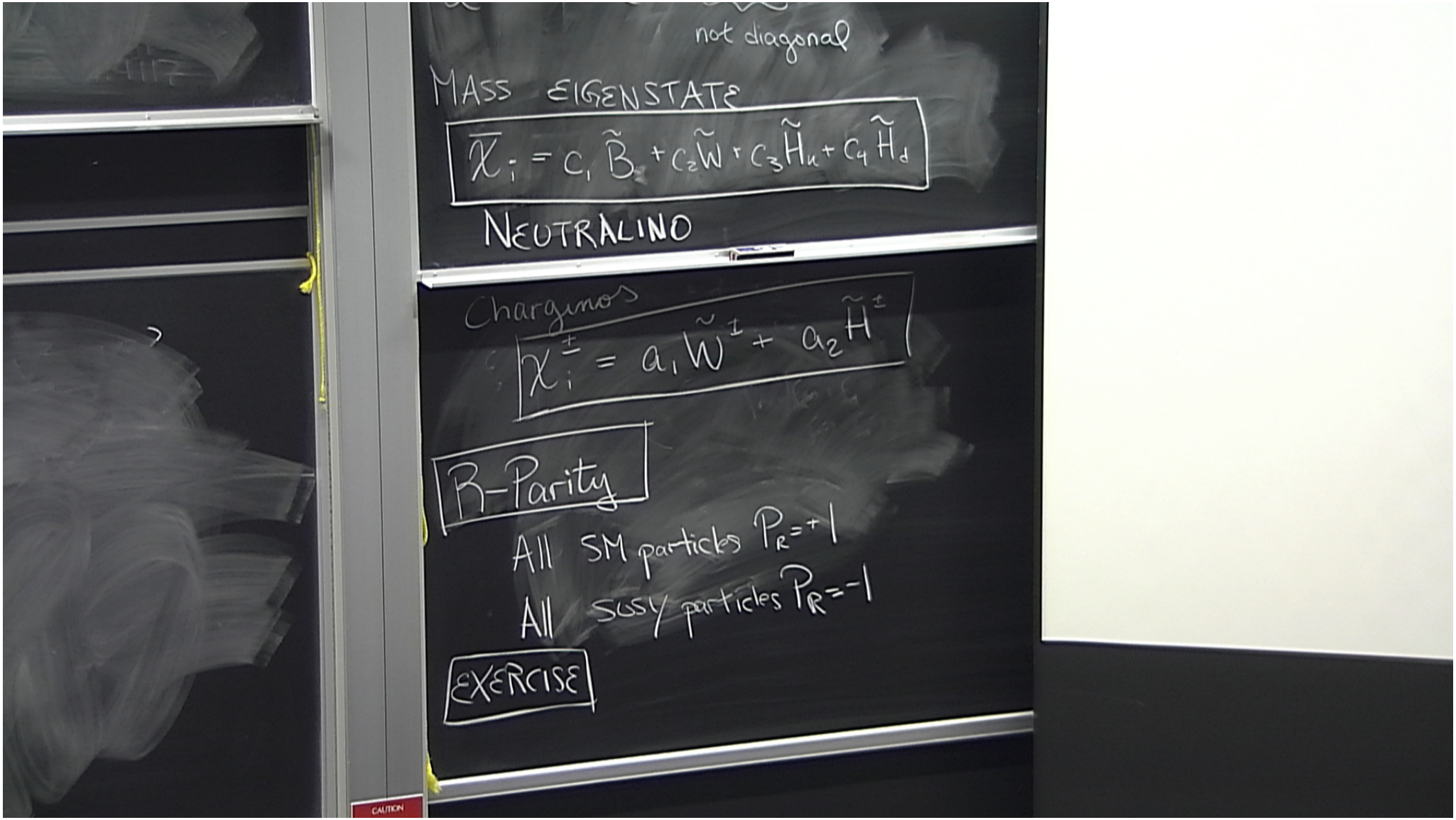
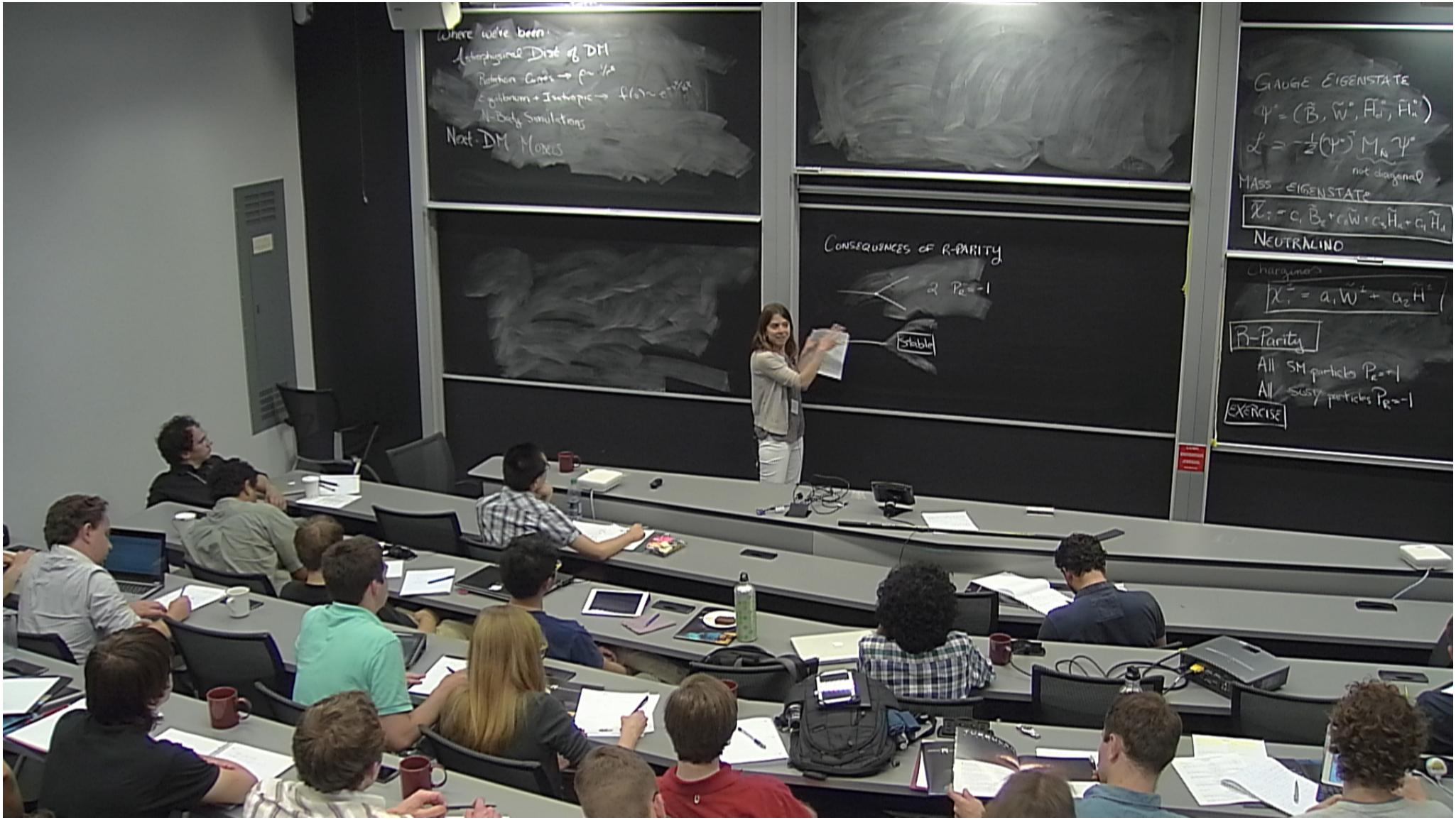
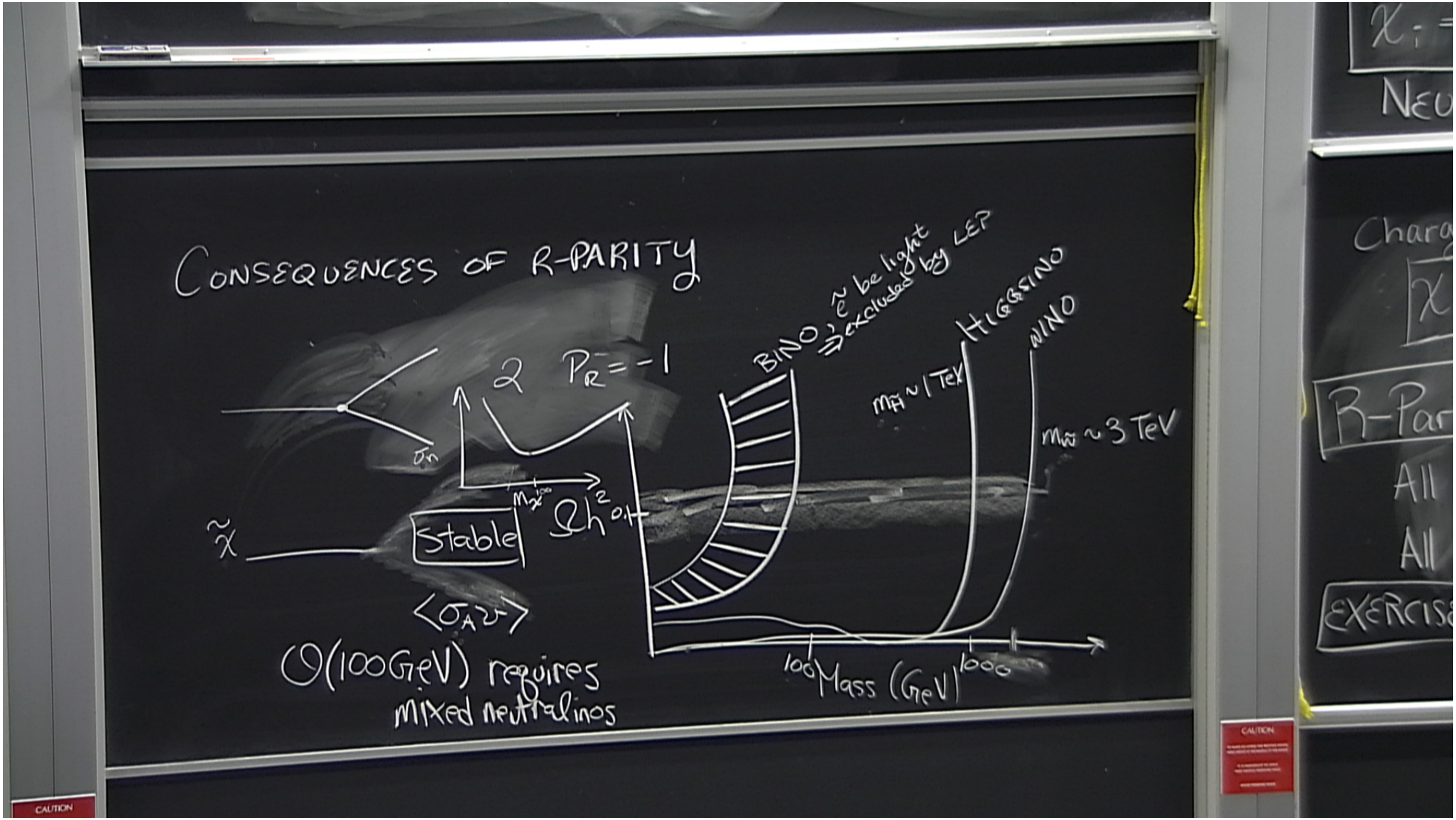
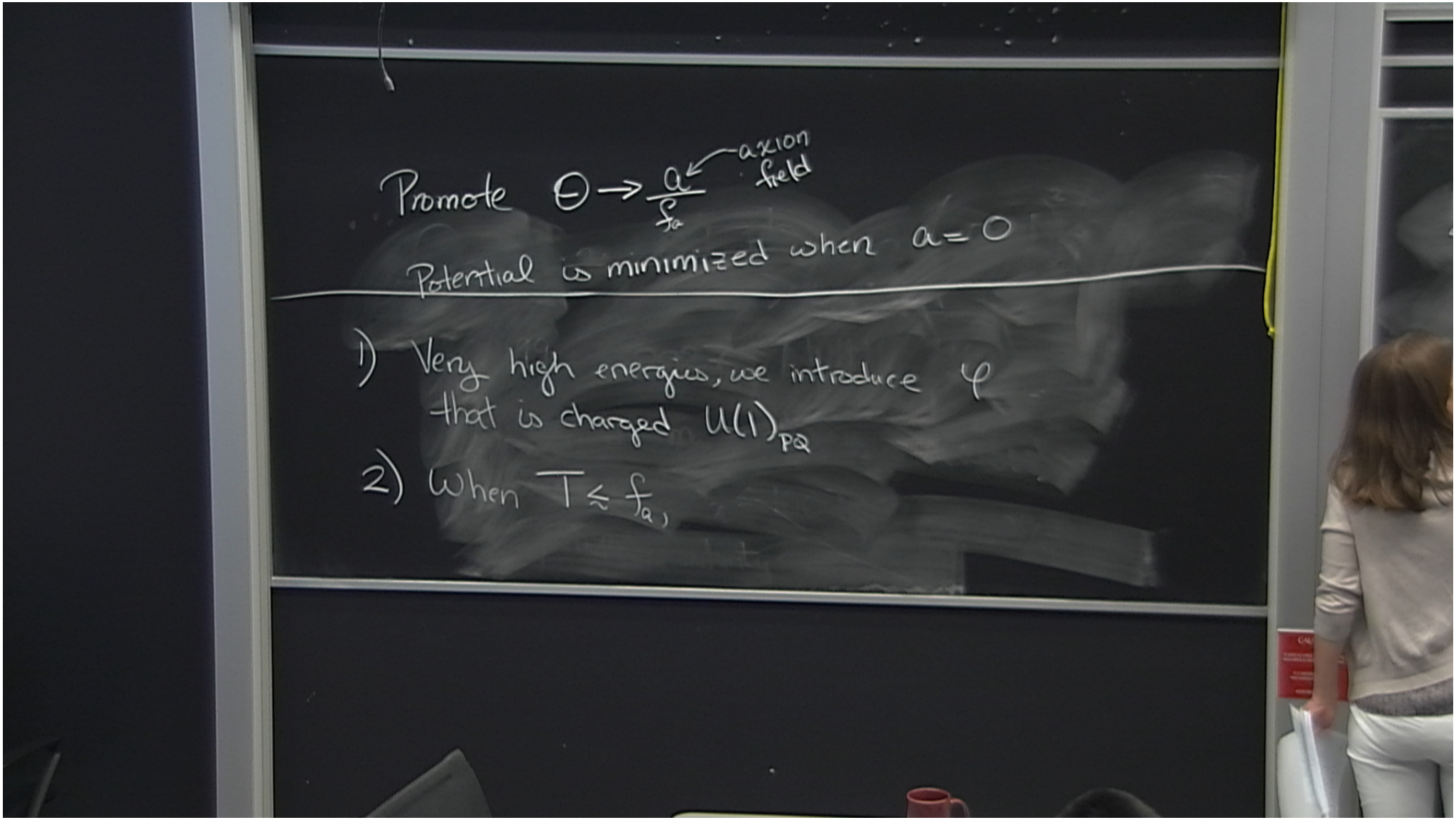

Case Study: SUSY Neutralino
(natural WIMP candidate)
Supersymmetry: symmetry that relates bosons + fermions
NAME
BOSON/SCALAR
SPIN-1/2
winos, W bosons
bino, B boson
CAUTION

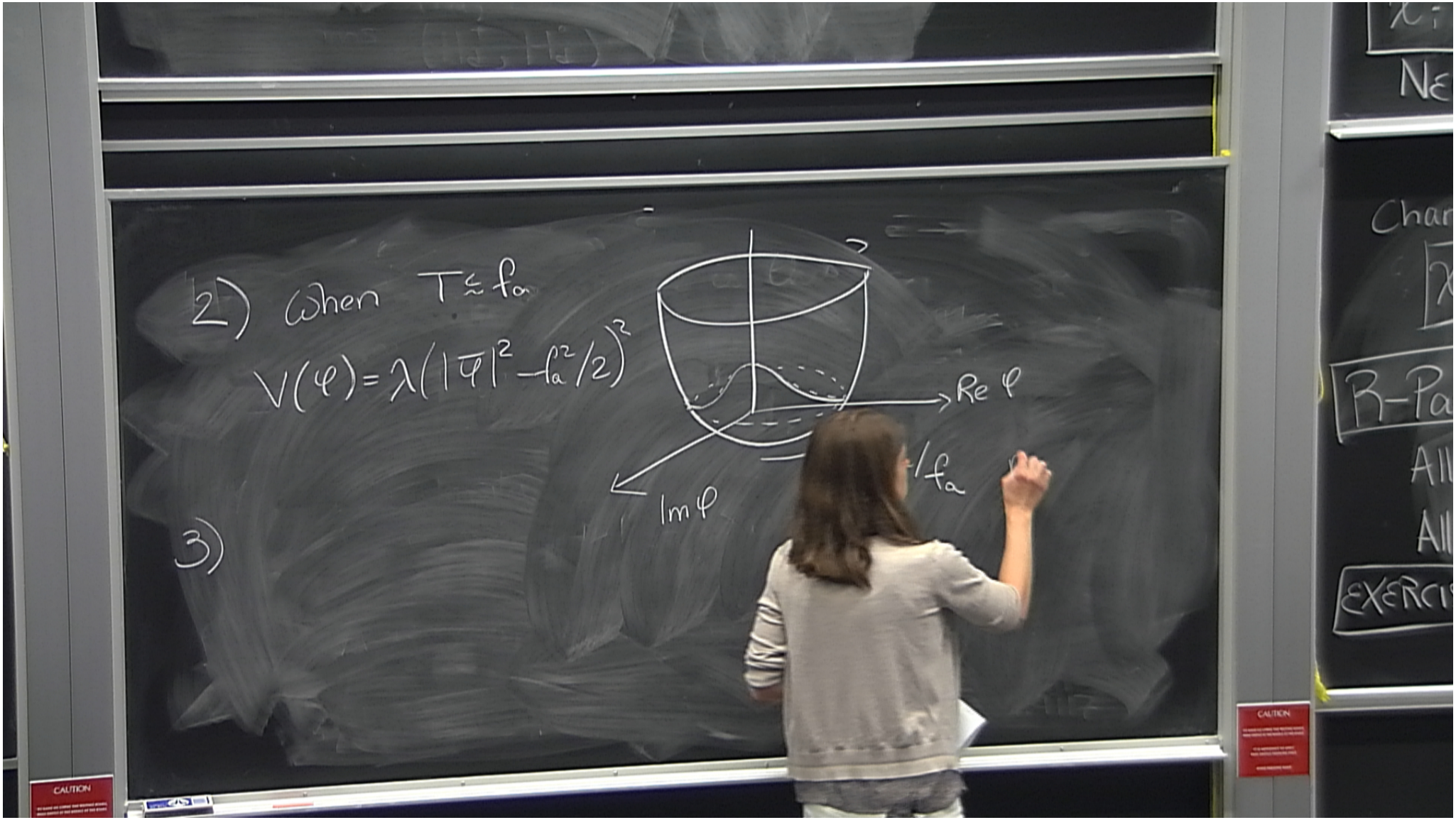

Case Study: SUSY Neutralino
(natural WIMP candidate)
Supersymmetry: symmetry that relates bosons + fermions
NAME
BOSON/SCALAR
SPIN-½
winos, W bosons
bino, B boson
Higgs, Higgsinos
MIXING AFTER ELECTROWEAK SB
CAUTION


not diagonal
MASS EIGENSTATE
$\chi_i = c_1 \tilde{B} + c_2 \tilde{W} + c_3 \tilde{H}_u + c_4 \tilde{H}_d$
NEUTRALINO
Charginos
$\chi_i^{\pm} = a_1 \tilde{W}^{\pm} + a_2 \tilde{H}^{\pm}$
R-Parity
All SM particles $P_R = +1$
All susy particles $P_R = -1$
EXERCISE
CAUTION


Where we've been:
Next: DM Models
Gauge Eigenstate
not diagonal
Mass Eigenstate
Neutralino
Consequences of R-Parity
Stable
R-Parity
All SM particles
All SUSY particles
EXERCISE

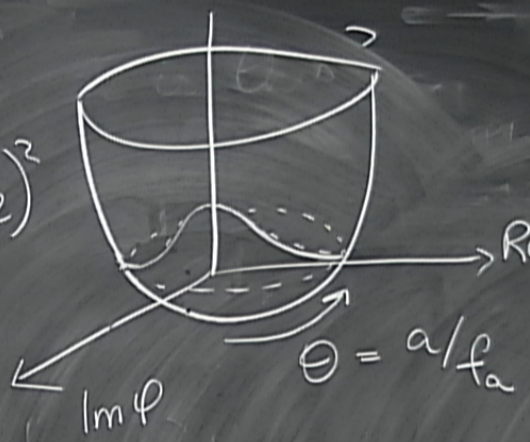

CONSEQUENCES OF R-PARITY
2
$P_R = -1$
$\tilde{\chi}$
Stable
$\Omega h^2_{0.1}$
$\langle \sigma_A v \rangle$
$\mathcal{O}(100\,GeV)$ requires
mixed neutralinos
BINO, $\tilde{e}$ be light
$\Rightarrow$ excluded by LEP
HIGGSINO
WINO
$m_{\tilde{H}} \sim 1$ TeV
$m_{\tilde{W}} \sim 3$ TeV
log Mass (GeV)
1000


Promote $\theta \to \frac{a}{f_a}$
axion field
Potential is minimized when $a = 0$
1) Very high energies, we introduce φ that is charged $U(1)_{PQ}$
2) When $T \lesssim f_a$,


2) when T ≃ fa
V(φ) = λ(|φ|² − fa²/2)²
Re φ
Im φ
/fa
3)

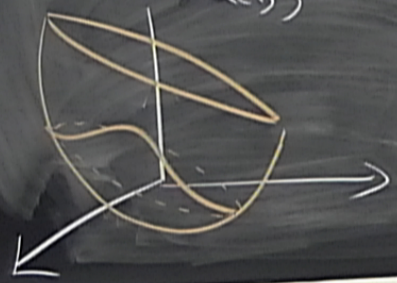
2) When $T \lesssim f_a$

$$V(\varphi) = \lambda(|\varphi|^2 - f_a^2/2)^2$$



$\theta = a/f_a$ massless

3) $T \sim \Lambda_{QCD}$, QCD instanton effects give axion mass

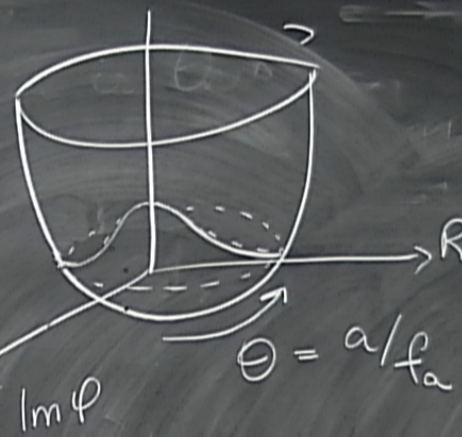


Mixed neutralinos

Mass (GeV)

2) When $T \lesssim f_a$

$$V(\varphi) = \lambda(|\varphi|^2 - f_a^2/2)^2$$



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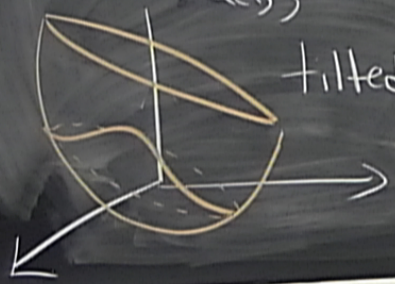
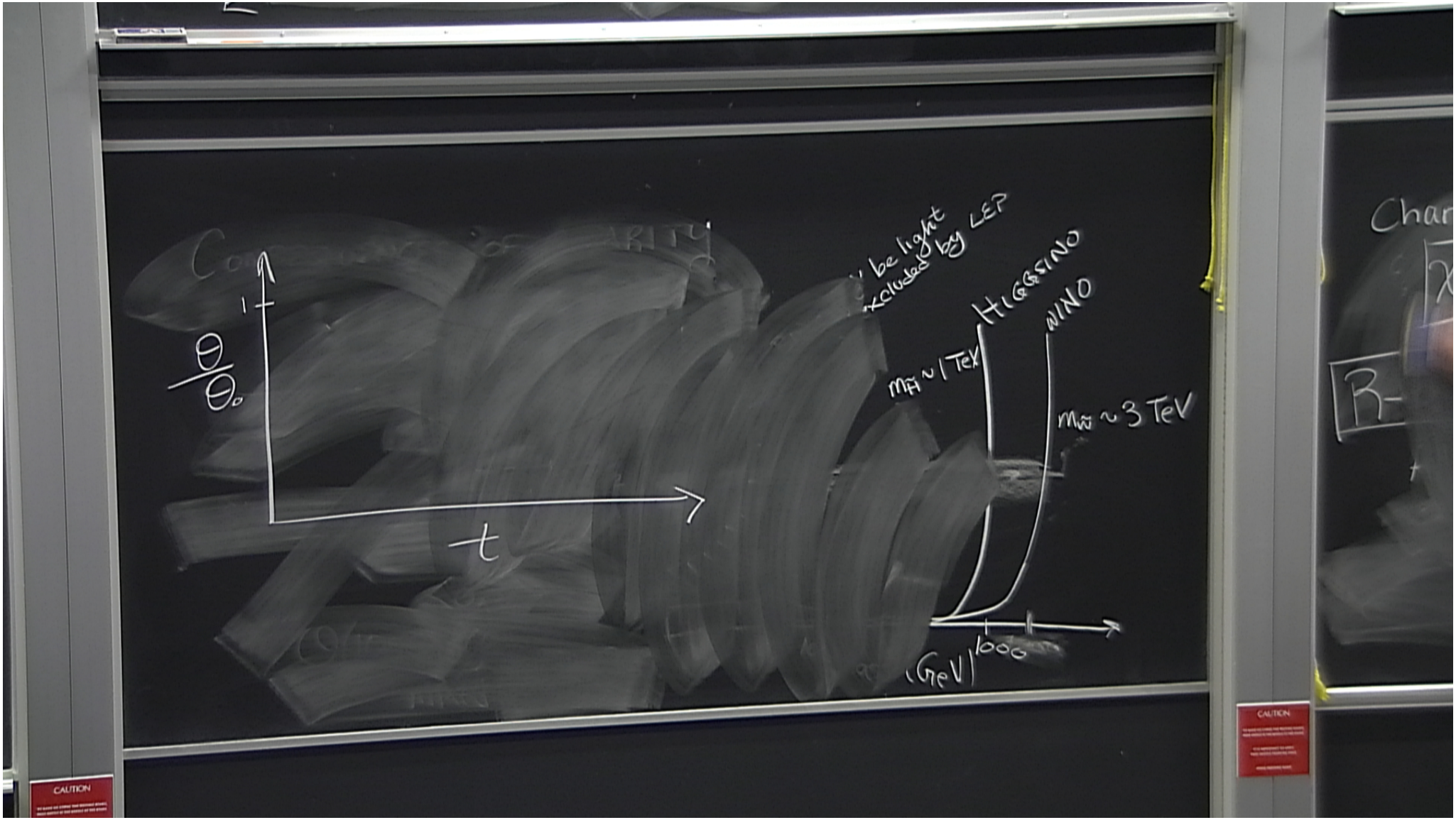
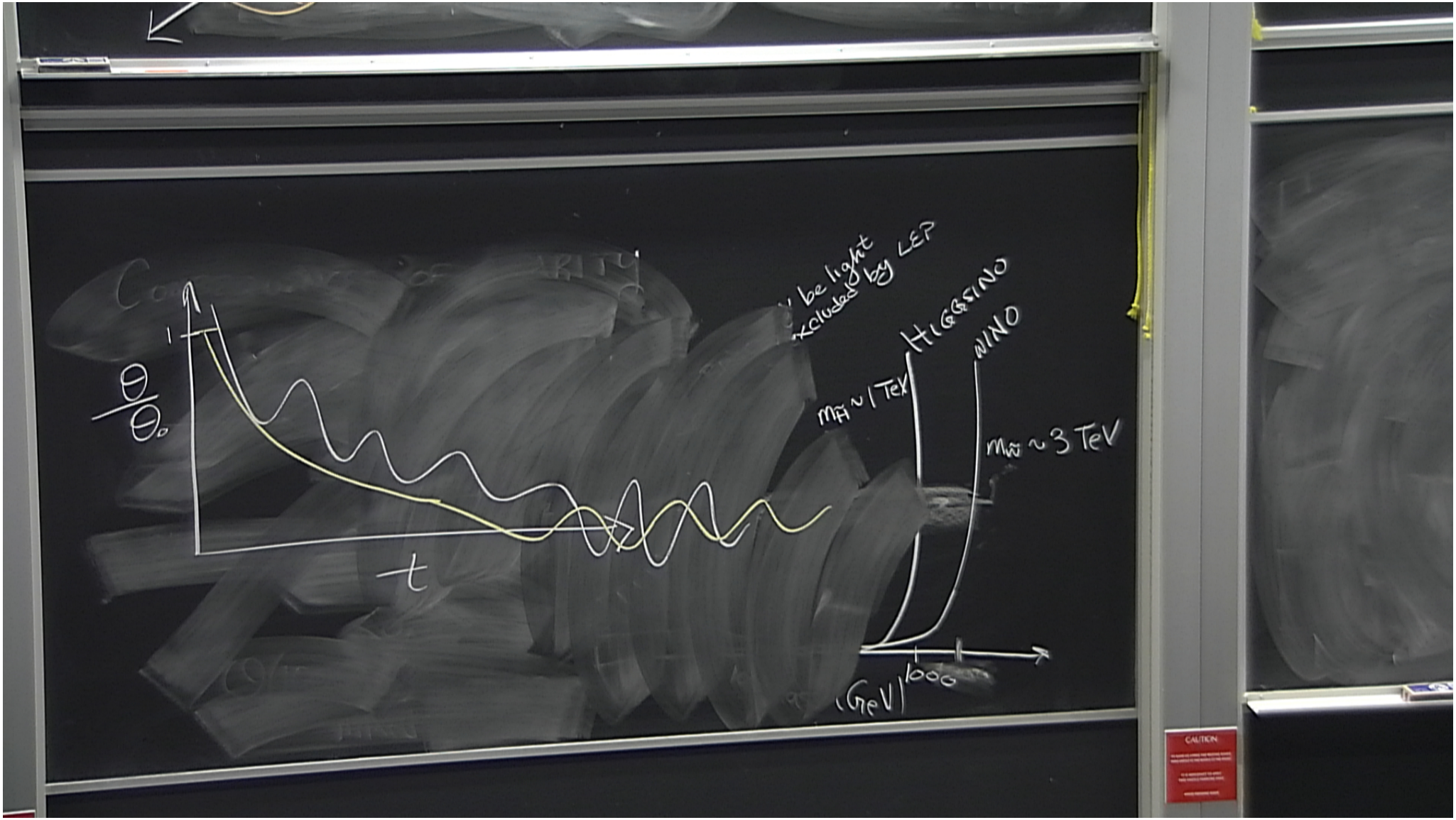


tilted potential

Mixed neutralinos

Mass (GeV)


θ/θ₀
1
t
be light
excluded by LEP
HIGGSINO
WINO
$m_{\tilde{H}} \sim 1$ TeV
$m_{\tilde{W}} \sim 3$ TeV
(GeV)
1000


be light
excluded by LEP
HIGGSINO
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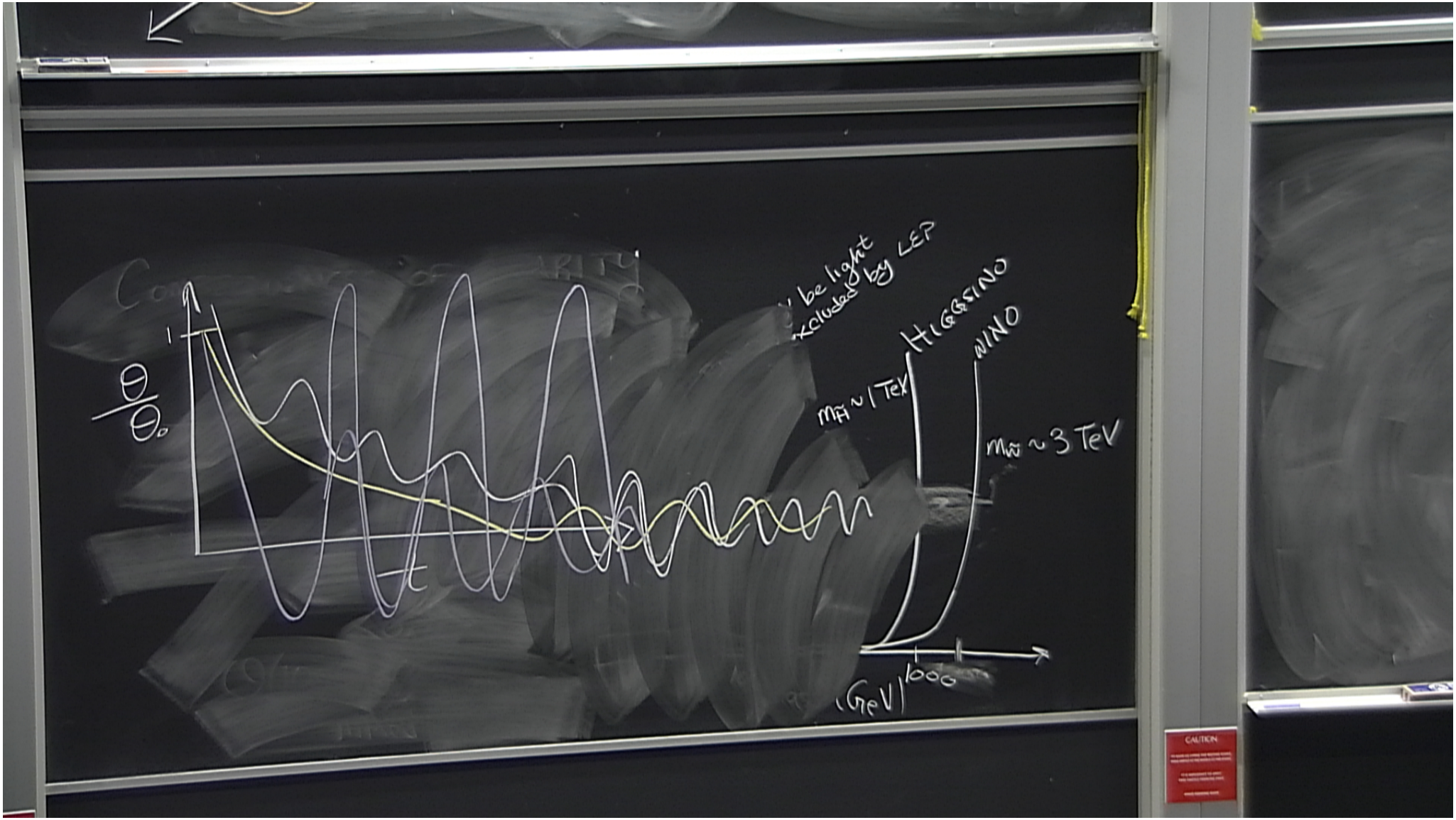
$m_{\tilde{H}} \sim 1$ TeV
$m_{\tilde{w}} \sim 3$ TeV
1000
(GeV)
$\frac{\theta}{\theta_0}$
1
t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$m_{\tilde{H}} \sim 1$ TeV
$m_{\tilde{w}} \sim 3$ TeV
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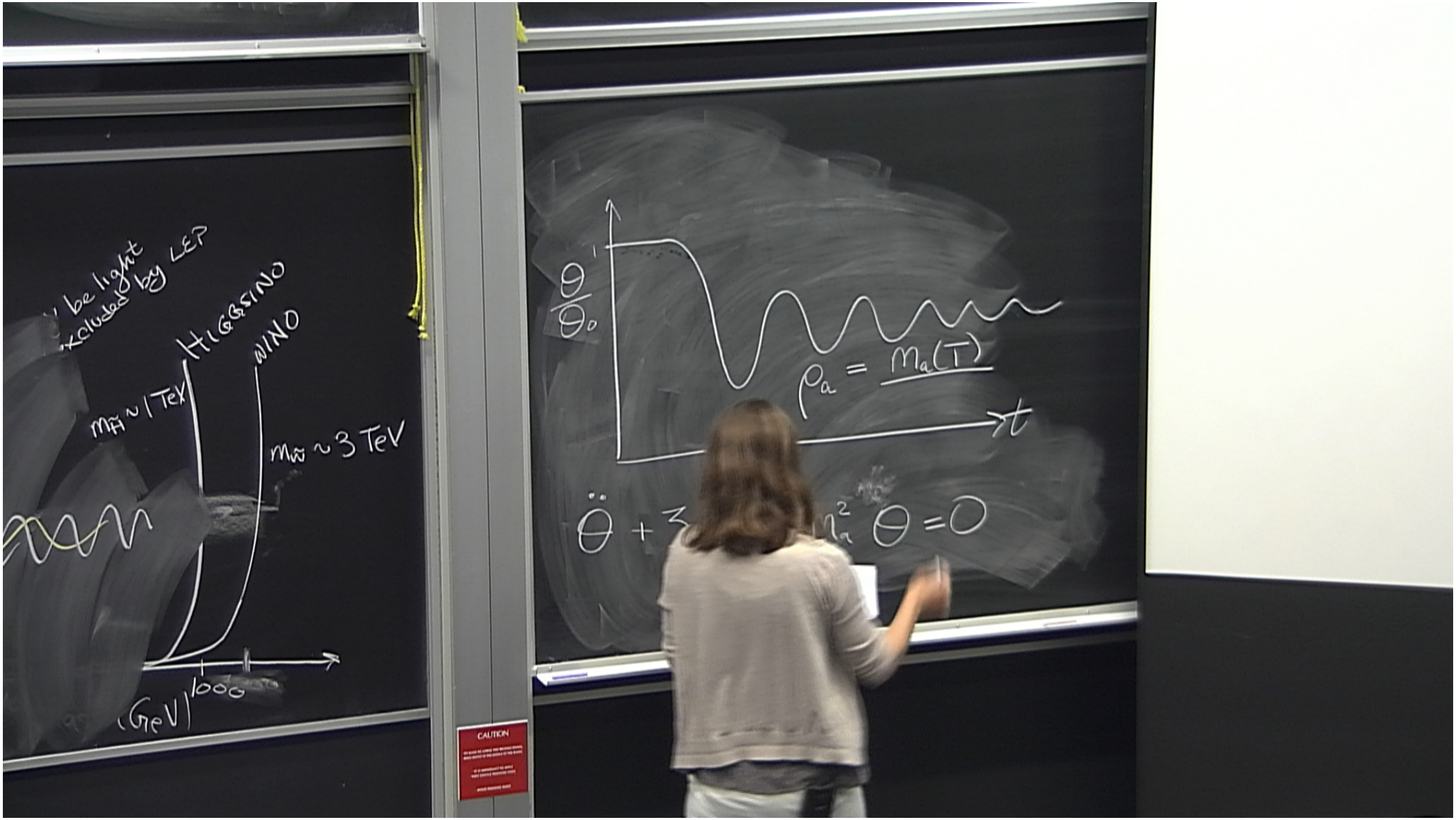
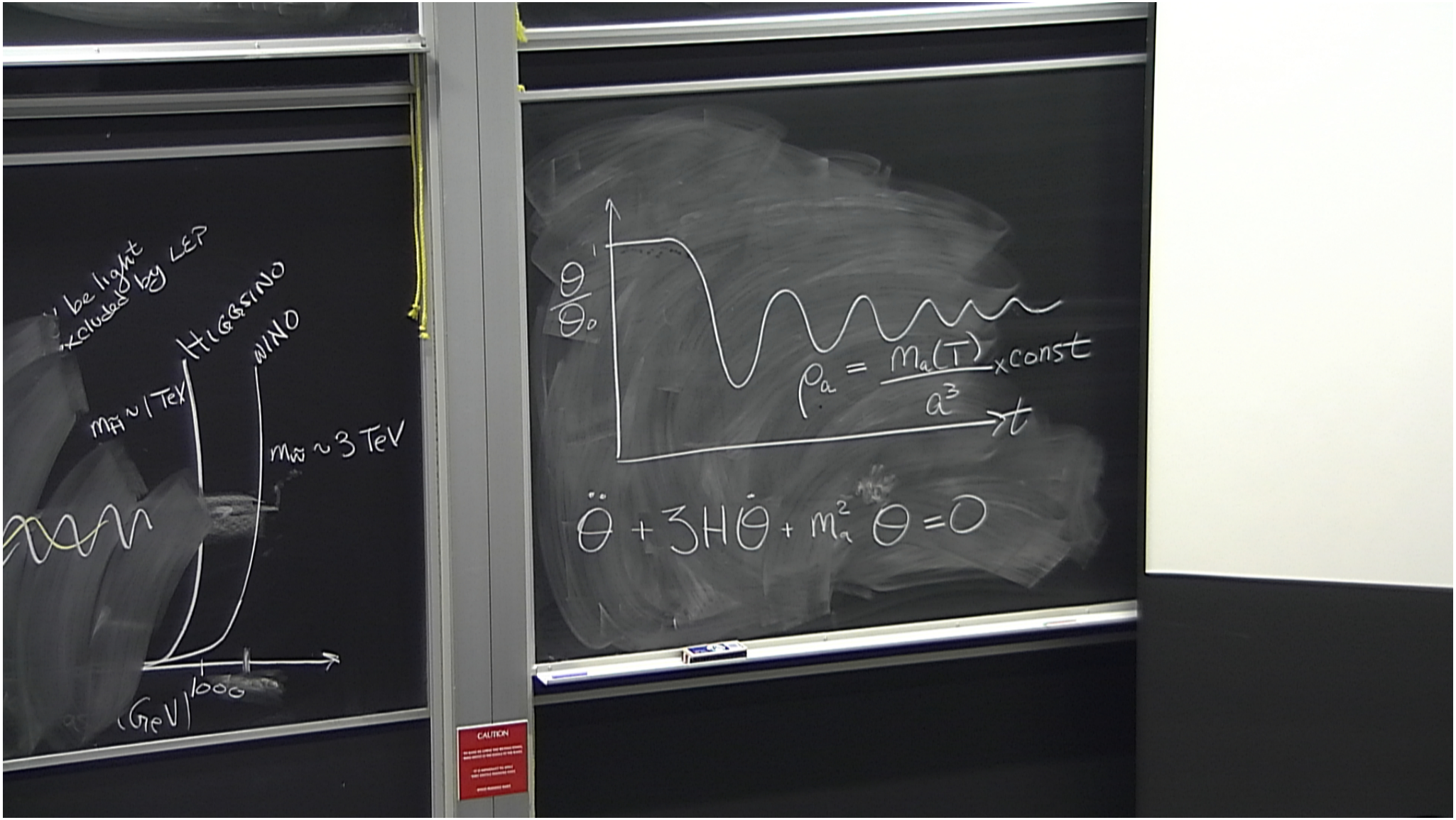
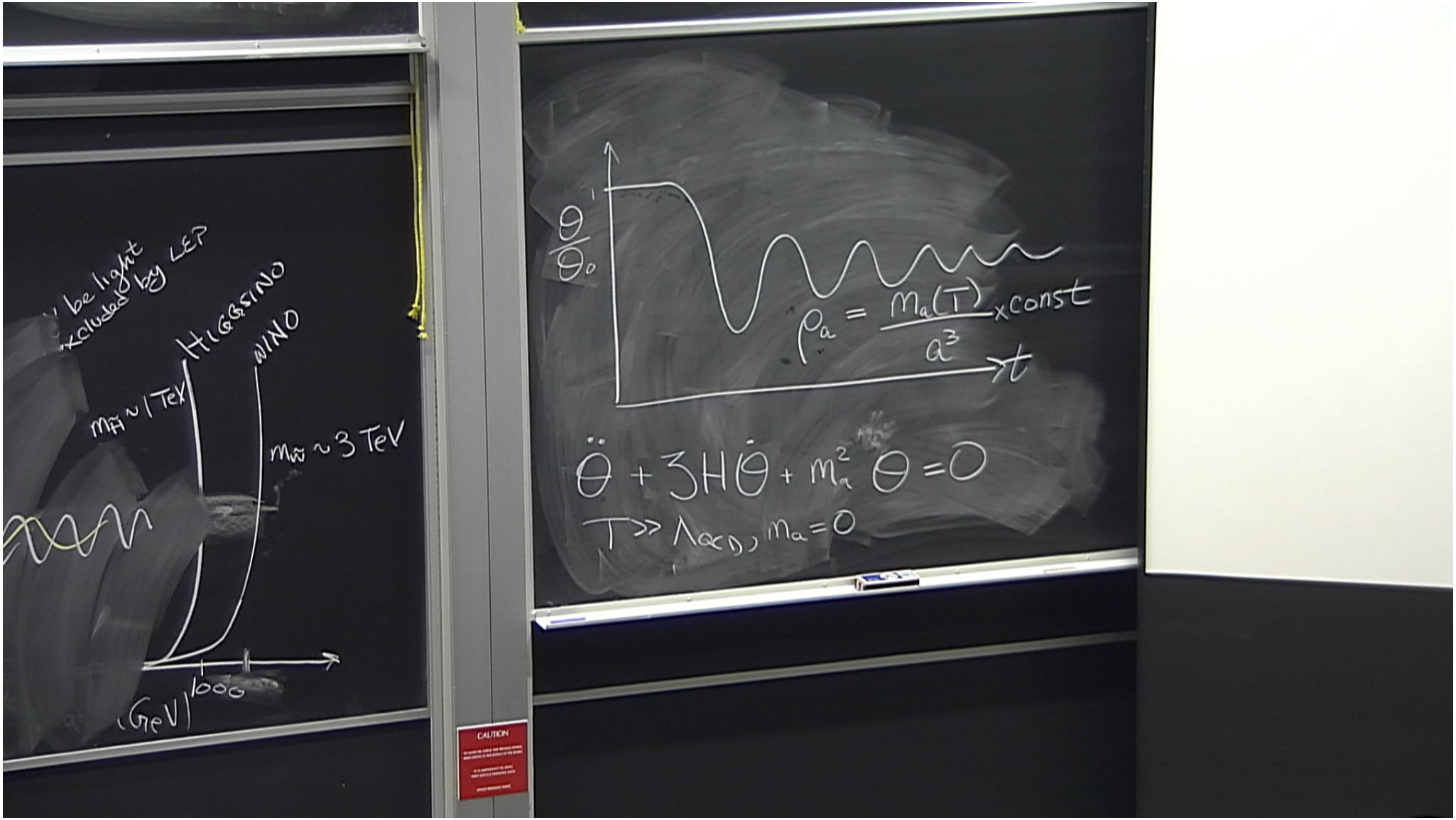
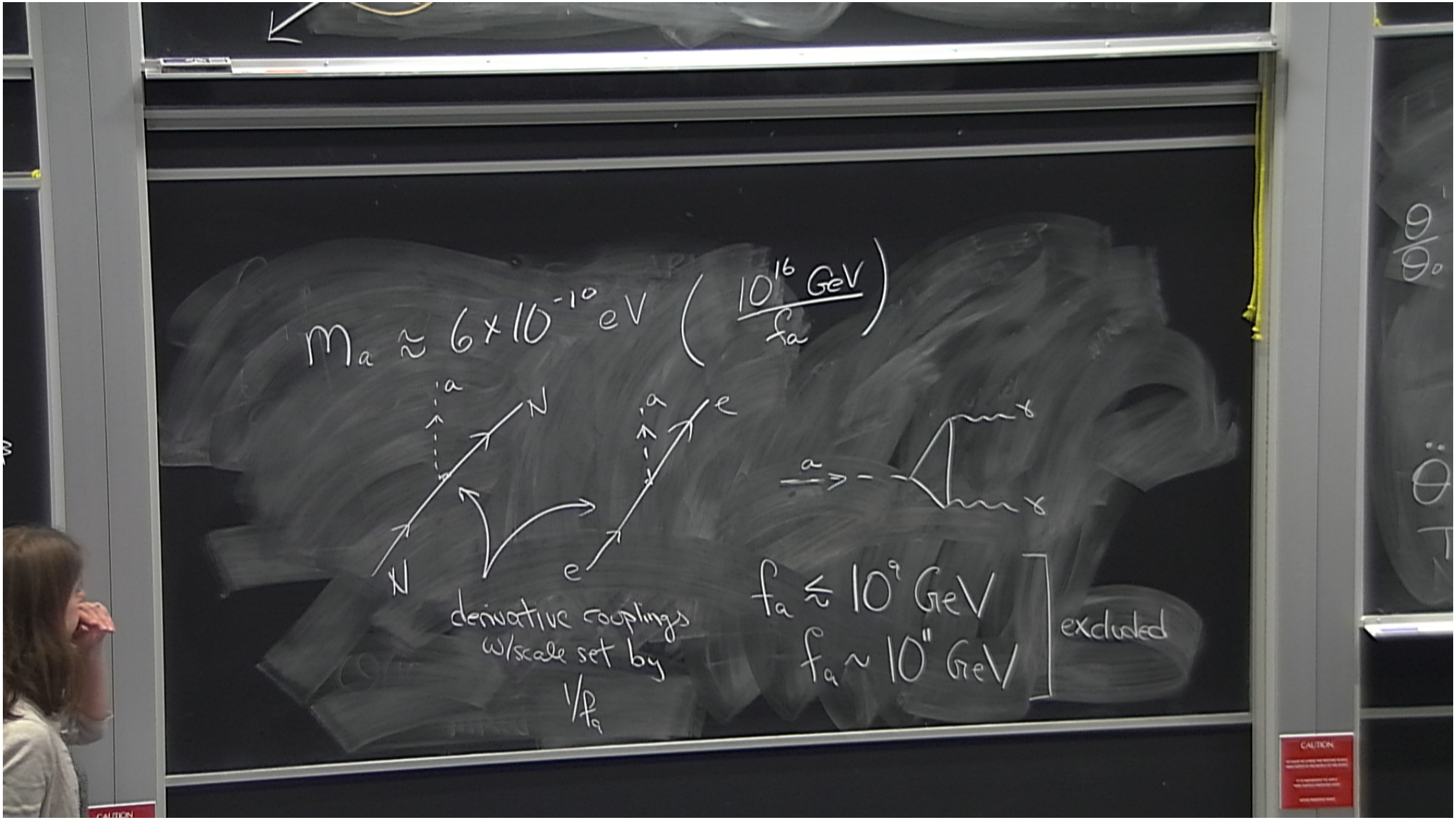

be light
excluded by LEP
HIGGSINO
WINO
$m_{\tilde{H}} \sim 1$ TeV
$m_{\tilde{W}} \sim 3$ TeV
1000
(GeV)
$\frac{\theta}{\theta_0}$
$\rho_a = m_a(T)$
t
$\ddot{\theta} + 3$
$\theta = 0$
CAUTION


be light
excluded by LEP
HIGGSINO
WINO
$m_{\tilde{H}} \sim 1$ TeV
$m_{\tilde{W}} \sim 3$ TeV
1000
(GeV)
θ/θ_0
$\rho_a = \frac{m_a(T)}{a^3} \times \text{const}$
t
$\ddot{\theta} + 3H\dot{\theta} + m_a^2\theta = 0$
CAUTION


be light
excluded by LEP
HIGGSINO
WINO
$m_{\tilde{H}} \sim 1$ TeV
$m_{\tilde{w}} \sim 3$ TeV
(GeV)
1000
θ/θ_0
$\rho_a = \frac{m_a(T)}{a^3} \times \text{const}$
t
$\ddot{\theta} + 3H\dot{\theta} + m_a^2\theta = 0$
$T \gg \Lambda_{QCD}$, $m_a = 0$
CAUTION


$m_a \approx 6\times10^{-10}\,\text{eV}\left(\frac{10^{16}\,\text{GeV}}{f_a}\right)$
a
N
N
a
e
e
derivative couplings
w/scale set by
$1/f_a$
a
γ
γ
$f_a \lesssim 10^9$ GeV
$f_a \sim 10^{11}$ GeV
excluded