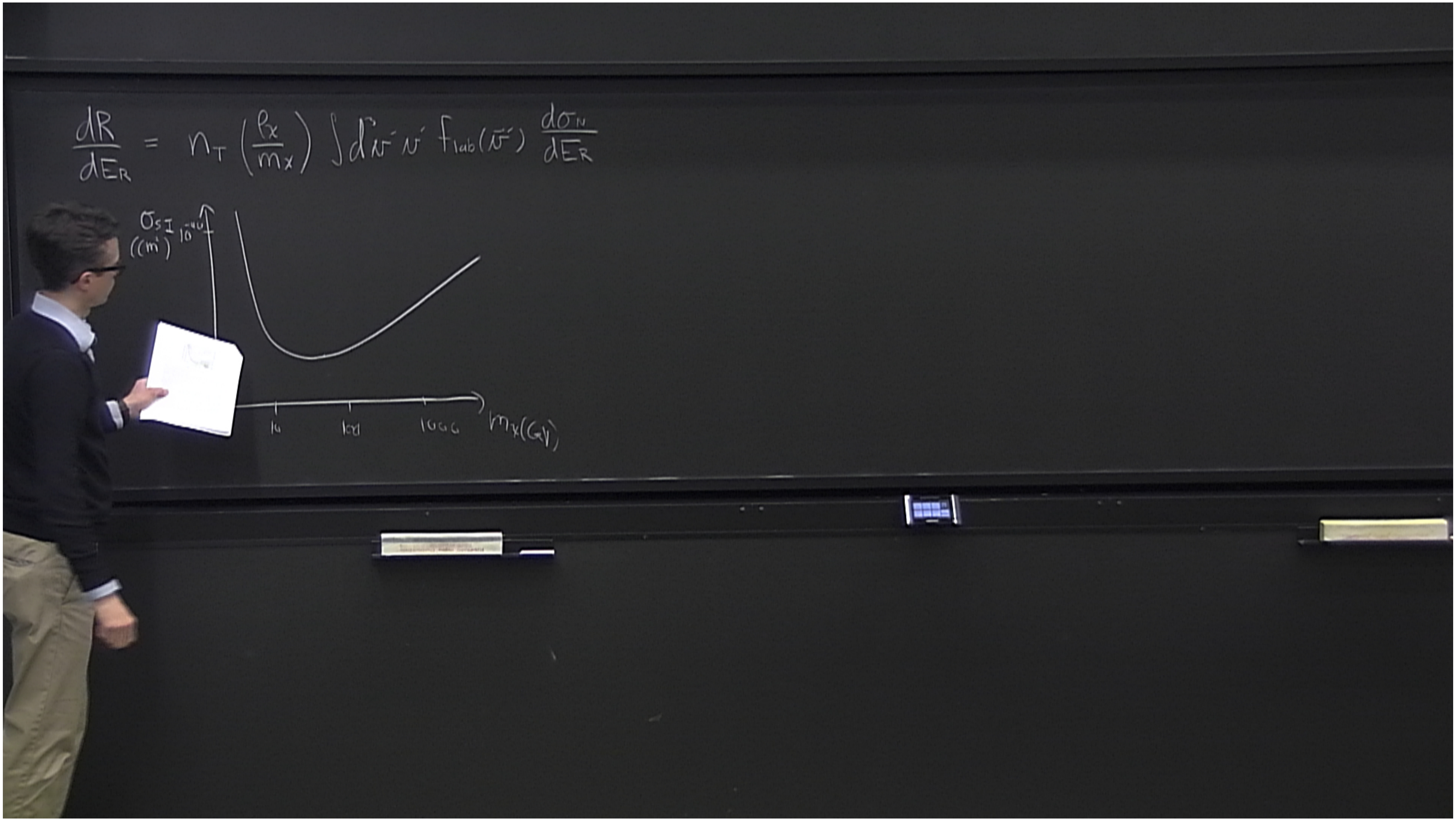
Title: 12/13 PSI - Explorations in Particle Theory Lecture 11

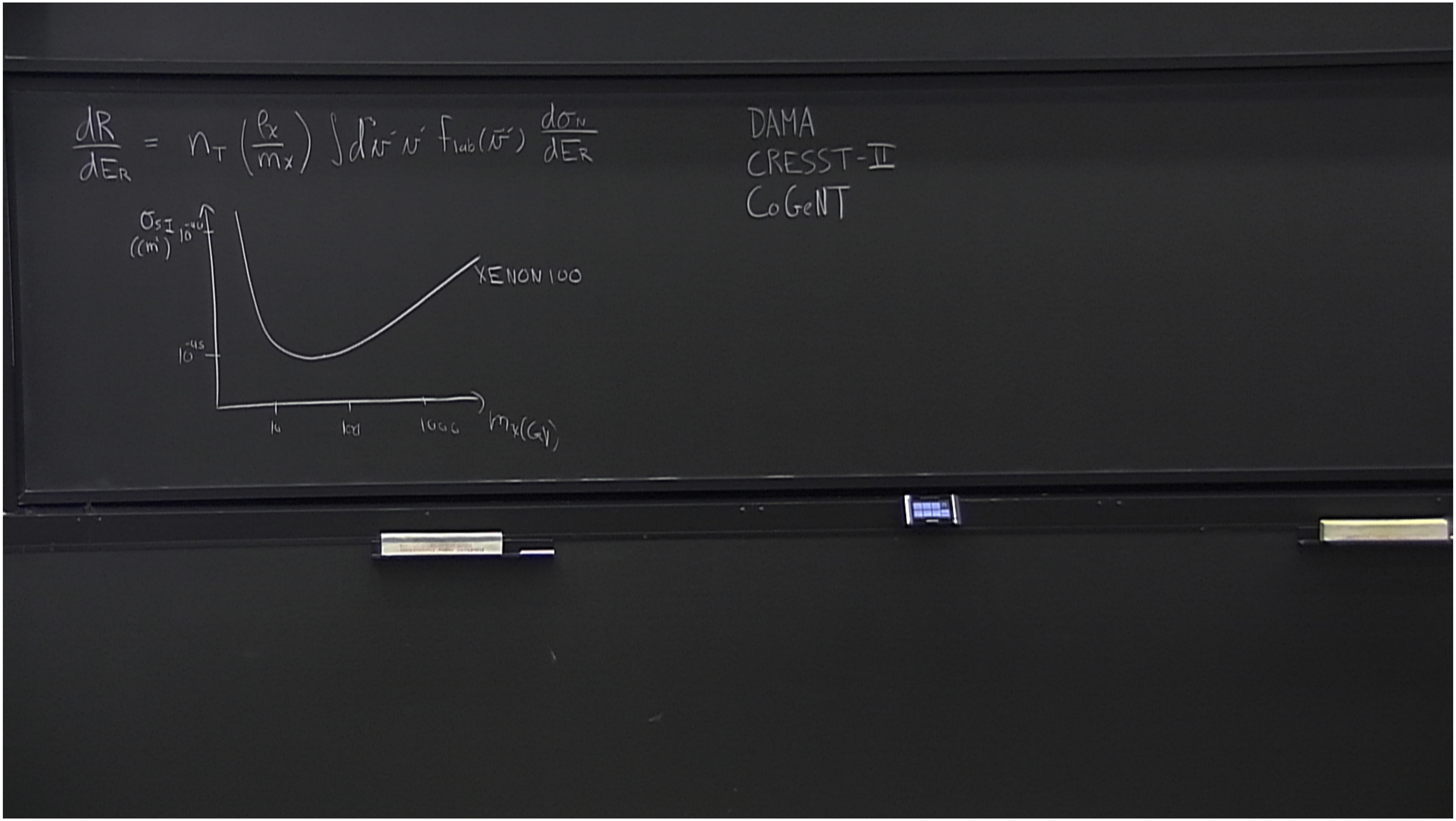
Date: Apr 02, 2013 10:15 AM

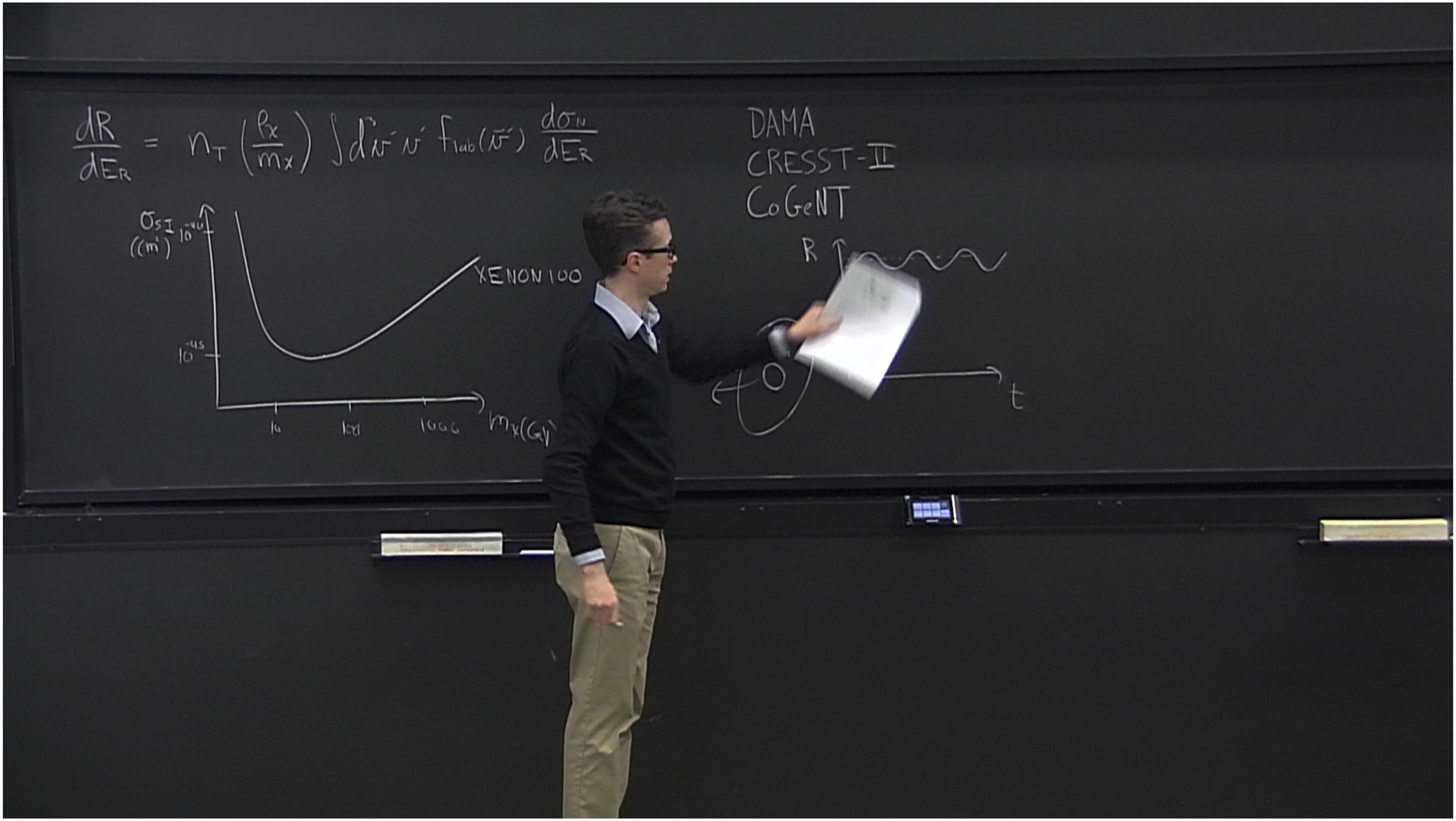
URL: http://pirsa.org/13040039

Abstract:

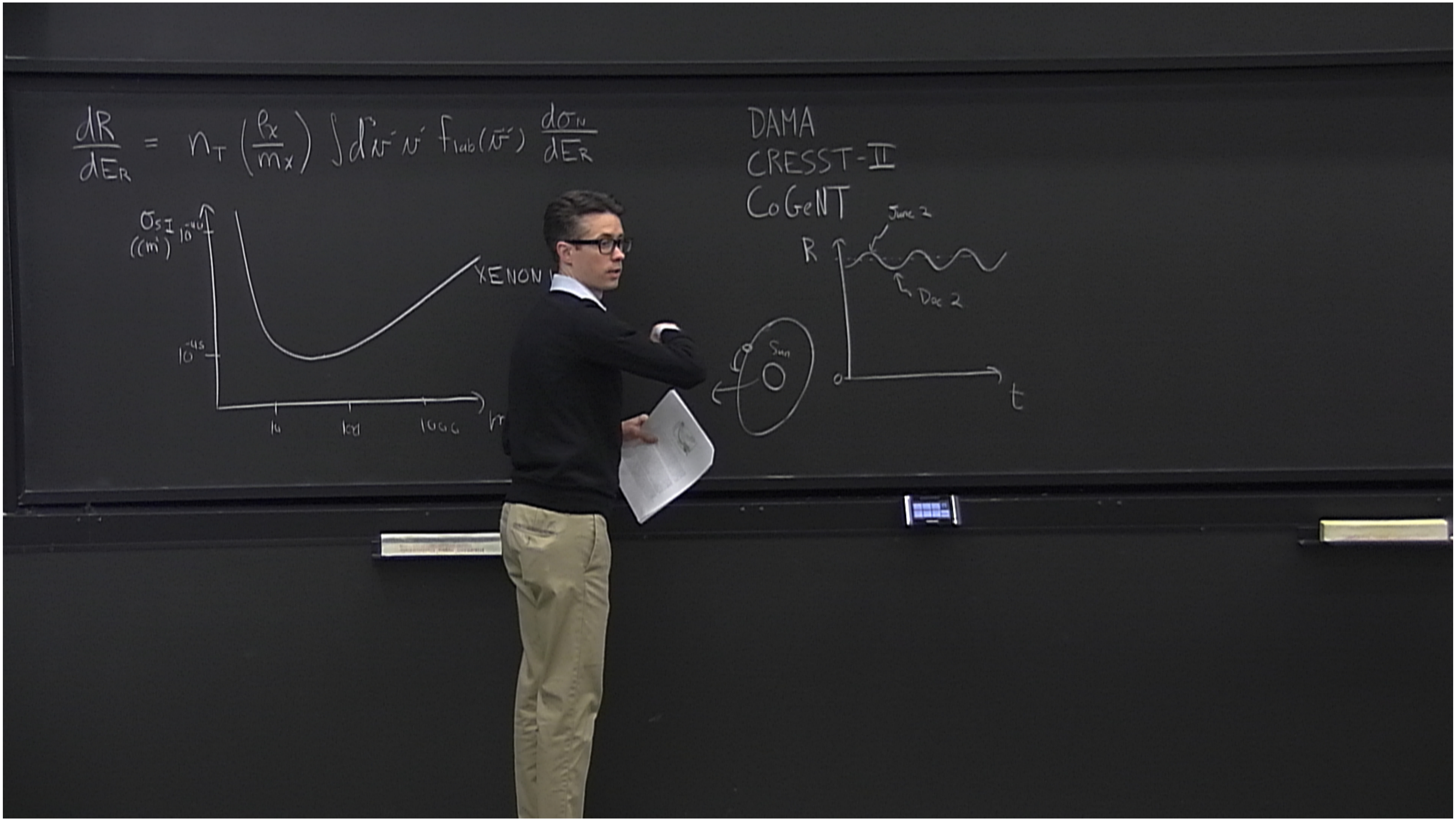


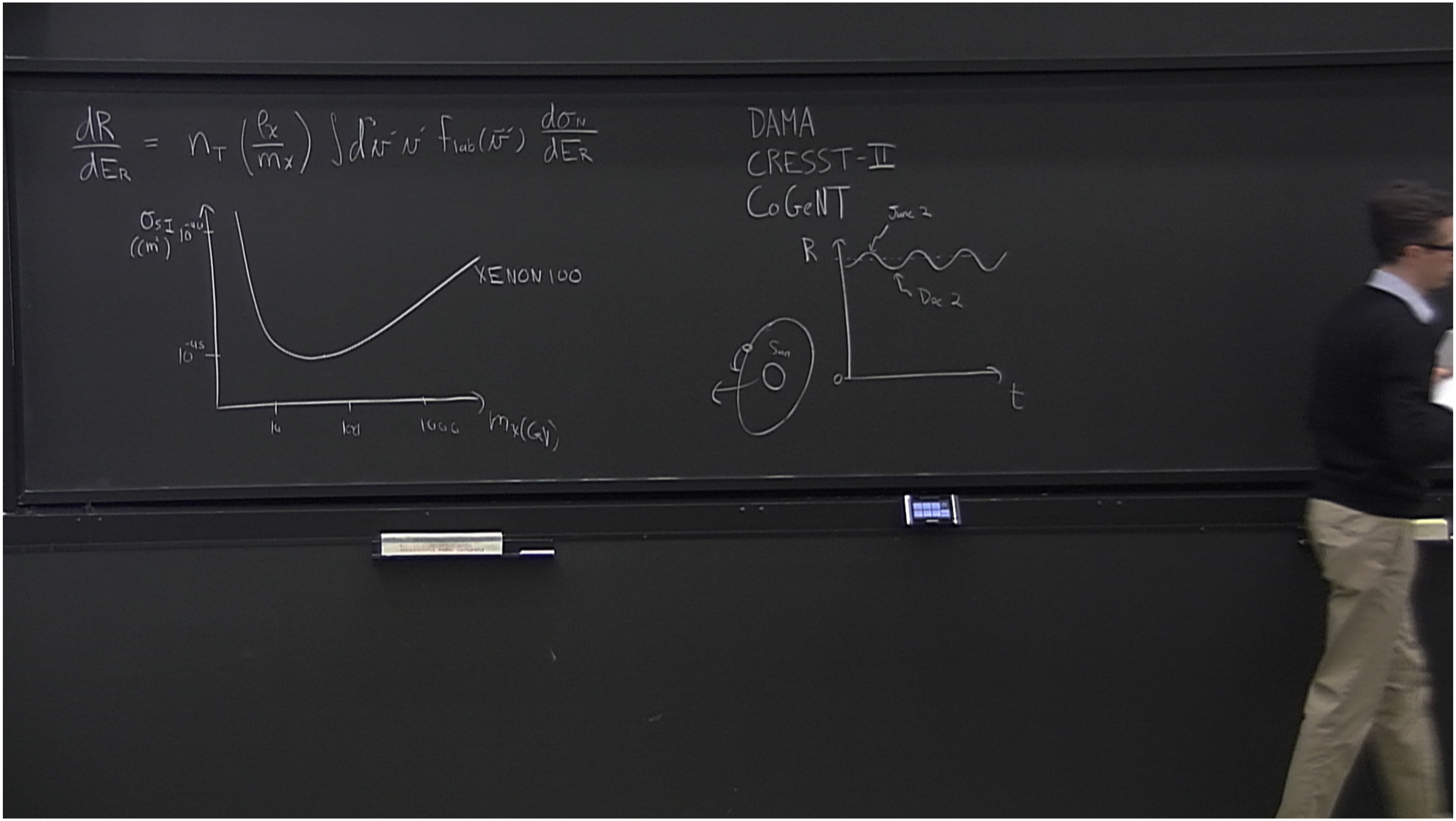
$\frac{dR}{dE_R} = n_T \left(\frac{\rho_\chi}{m_\chi}\right) \int d^3v \, v \, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
σ_{SI}
10^{-44}
m_χ (GeV)


$$\frac{dR}{dE_R} = n_T \left(\frac{\rho_\chi}{m_\chi}\right) \int d^3v \, v \, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$$
σ_{SI} (cm^2)
10^{-44}
10^{-45}
XENON100
10
100
1000
m_χ (GeV)
DAMA
CRESST-II
CoGeNT



$\frac{dR}{dE_R} = n_T \left(\frac{\rho_\chi}{m_\chi}\right) \int d^3v\, v\, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
DAMA
CRESST-II
CoGeNT
R
t
XENON100
σ_{SI}
(cm^2)
10^{-44}
10^{-45}
m_χ(GeV)


DAMA
CRESST-II
CoGeNT
June 2
Dec 2
R
t
Sun
XENON


$\frac{dR}{dE_R} = n_T \left(\frac{\rho_\chi}{m_\chi}\right) \int d\vec{v}\, v\, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
σ_{SI} (cm^2)
10^{-44}
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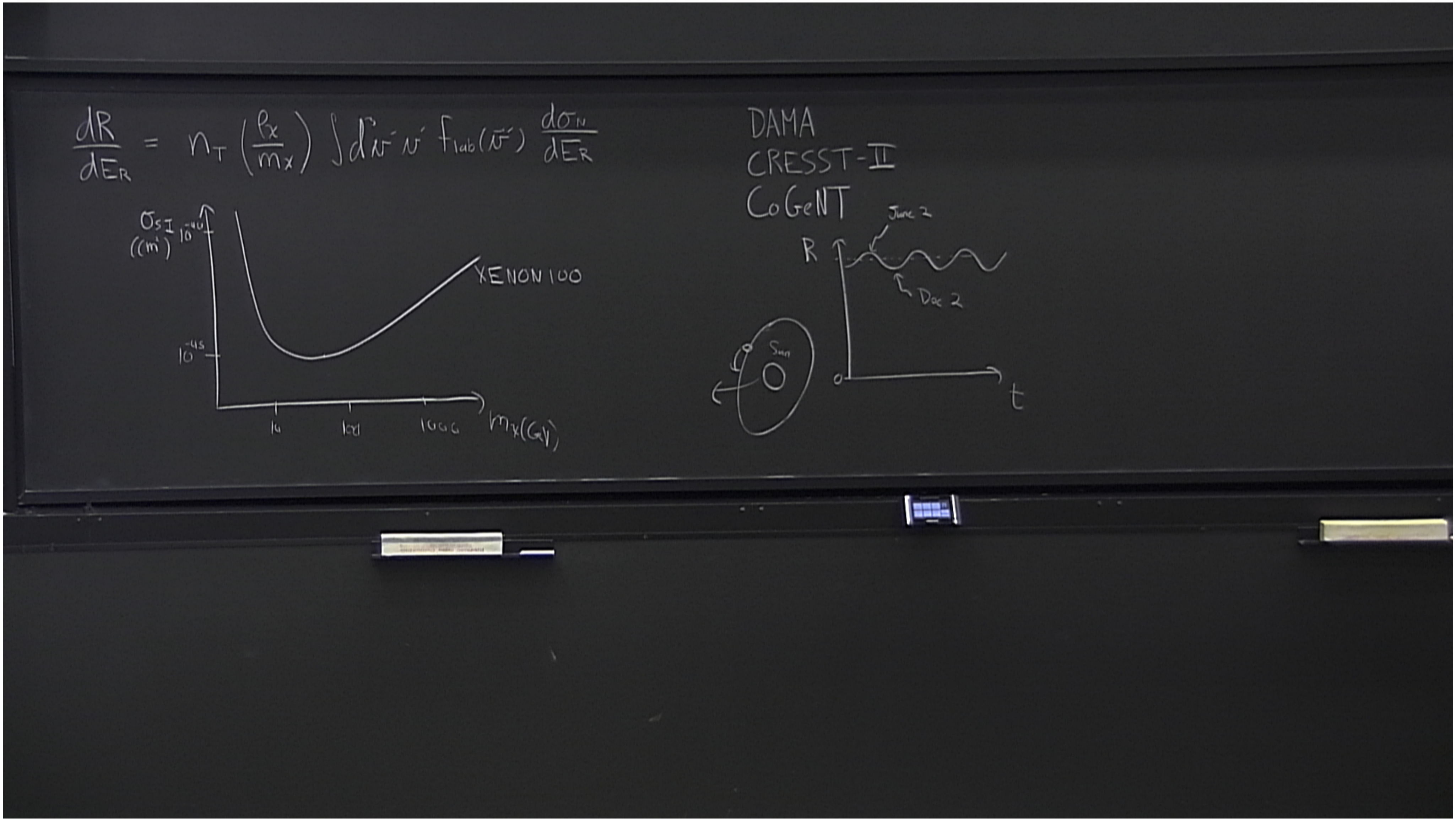
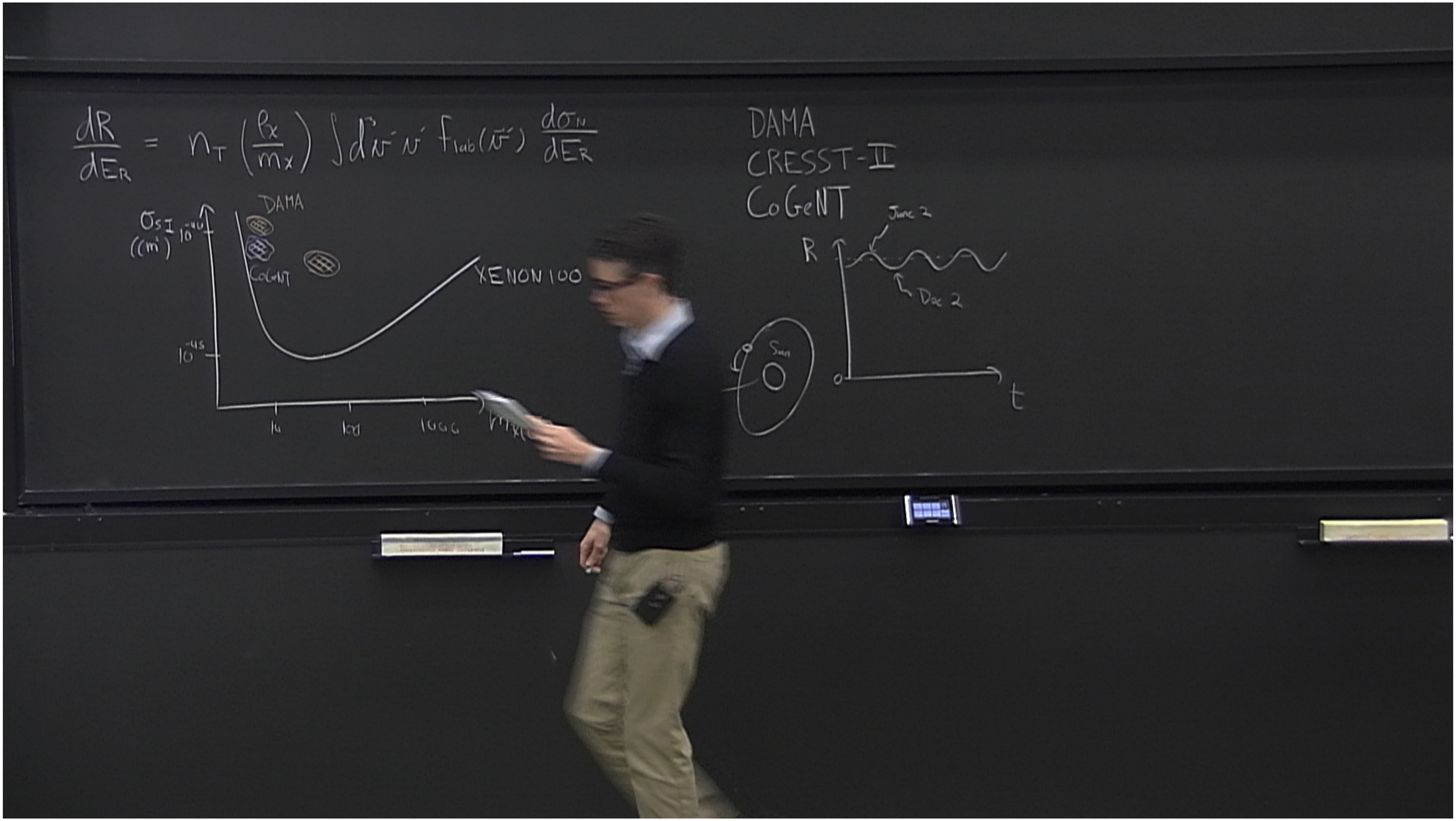
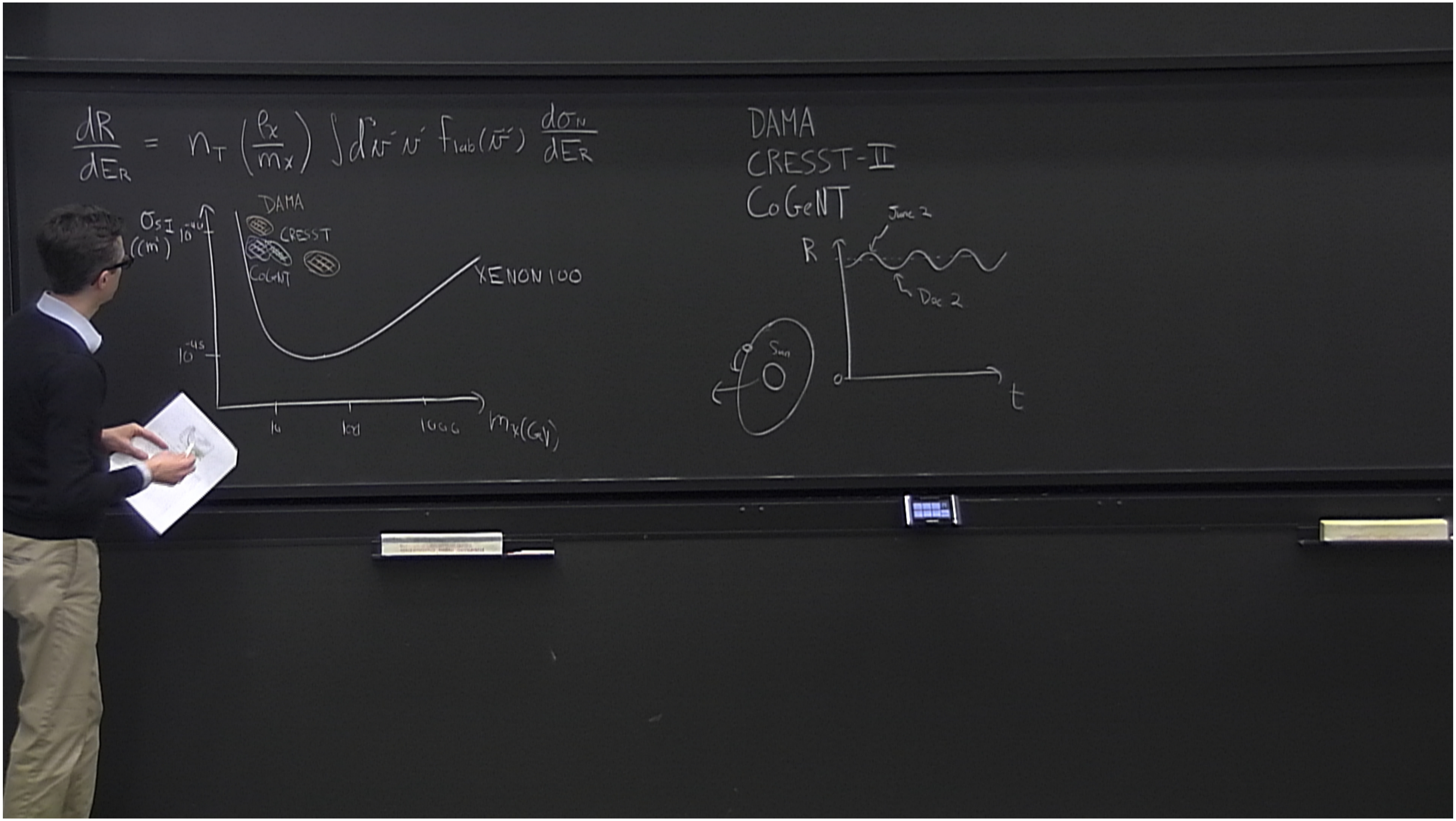
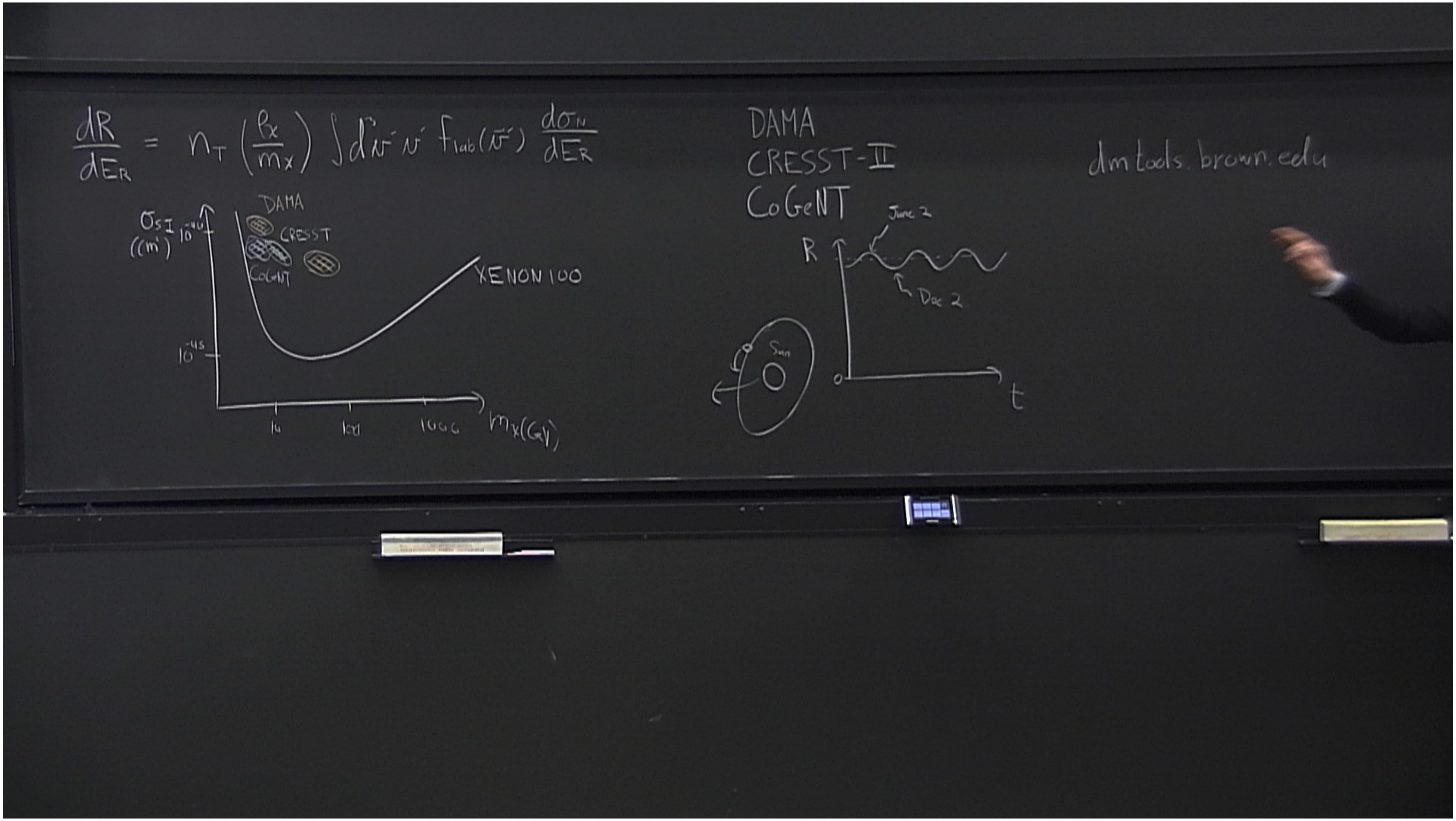
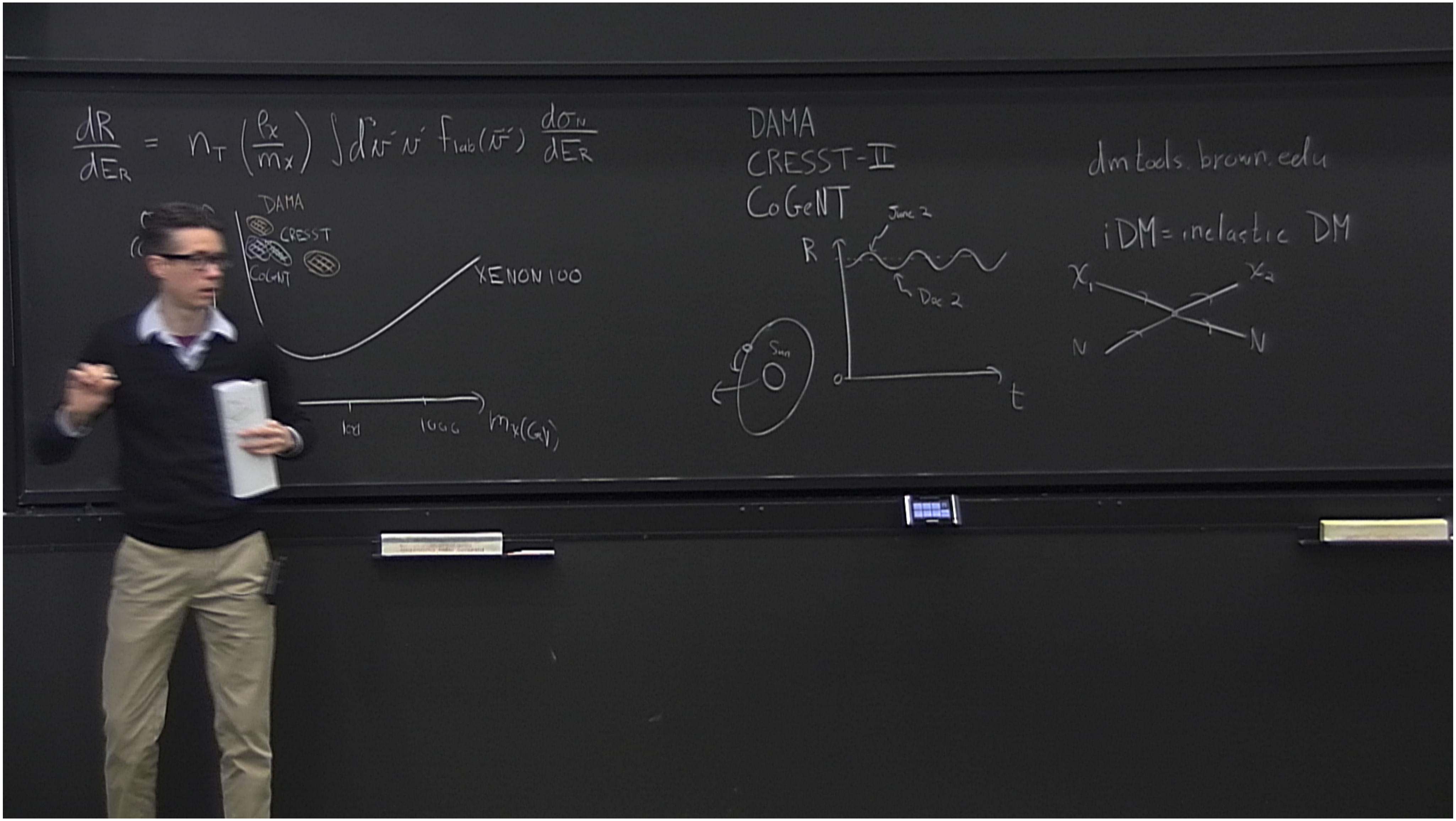
XENON100
1G
10G
100G
m_χ (GeV)
DAMA
CRESST-II
CoGeNT
June 2
R
Dec 2
Sun
t


$\frac{dR}{dE_R} = n_T \left(\frac{\rho_\chi}{m_\chi}\right) \int d\vec{v}\, v\, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
DAMA
CRESST-II
CoGeNT
XENON100
June 2
Dec 2
Sun
R
t

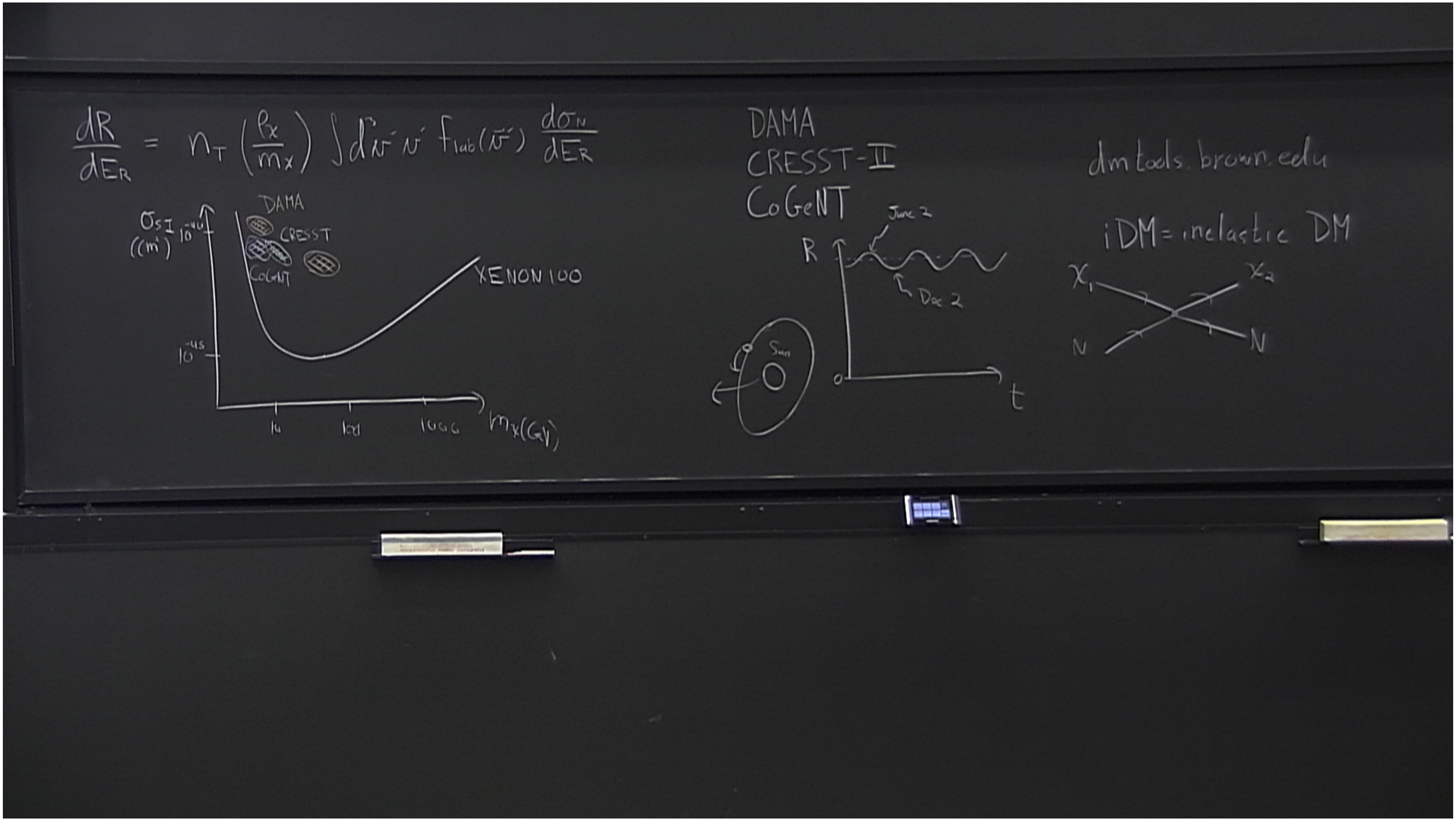

$\frac{dR}{dE_R} = n_T \left(\frac{\rho_x}{m_x}\right) \int d^3v\, v\, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
DAMA
CoGeNT
XENON100
DAMA
CRESST-II
CoGeNT
June 2
Dec 2
R
t
Sun


dR/dE_R = n_T (ρ_χ/m_χ) ∫ d³v v f_lab(v) dσ_N/dE_R
DAMA
CRESST
CoGeNT
XENON100
σ_SI (cm²)
10^-44
10^-45
1G
10G
100G
m_χ (GeV)
DAMA
CRESST-II
CoGeNT
June 2
Dec 2
R
t
Sun


$\frac{dR}{dE_R} = n_T \left(\frac{\rho_x}{m_x}\right) \int d^3v \, v \, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
DAMA
CRESST
CoGeNT
XENON100
σ_{SI} (cm^2)
10^{-44}
10^{-45}
m_x (GeV)
DAMA
CRESST-II
CoGeNT
June 2
Dec 2
R
t
Sun
dmtools.brown.edu



$\frac{dR}{dE_R} = n_T \left(\frac{\rho_\chi}{m_\chi}\right) \int d^3v\, v\, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
DAMA
CRESST
CoGeNT
XENON100
m_χ(GeV)
DAMA
CRESST-II
CoGeNT
June 2
Dec 2
R
t
Sun
dmtools.brown.edu
iDM = inelastic DM
χ_1
χ_2
N
N


$\frac{dR}{dE_R} = n_T \left(\frac{\rho_\chi}{m_\chi}\right) \int d^3v\, v\, f_{lab}(\vec{v}) \frac{d\sigma_N}{dE_R}$
DAMA
CRESST-II
CoGeNT
dmtools.brown.edu
iDM = inelastic DM
σ_{SI} (cm^2)
10^{-44}
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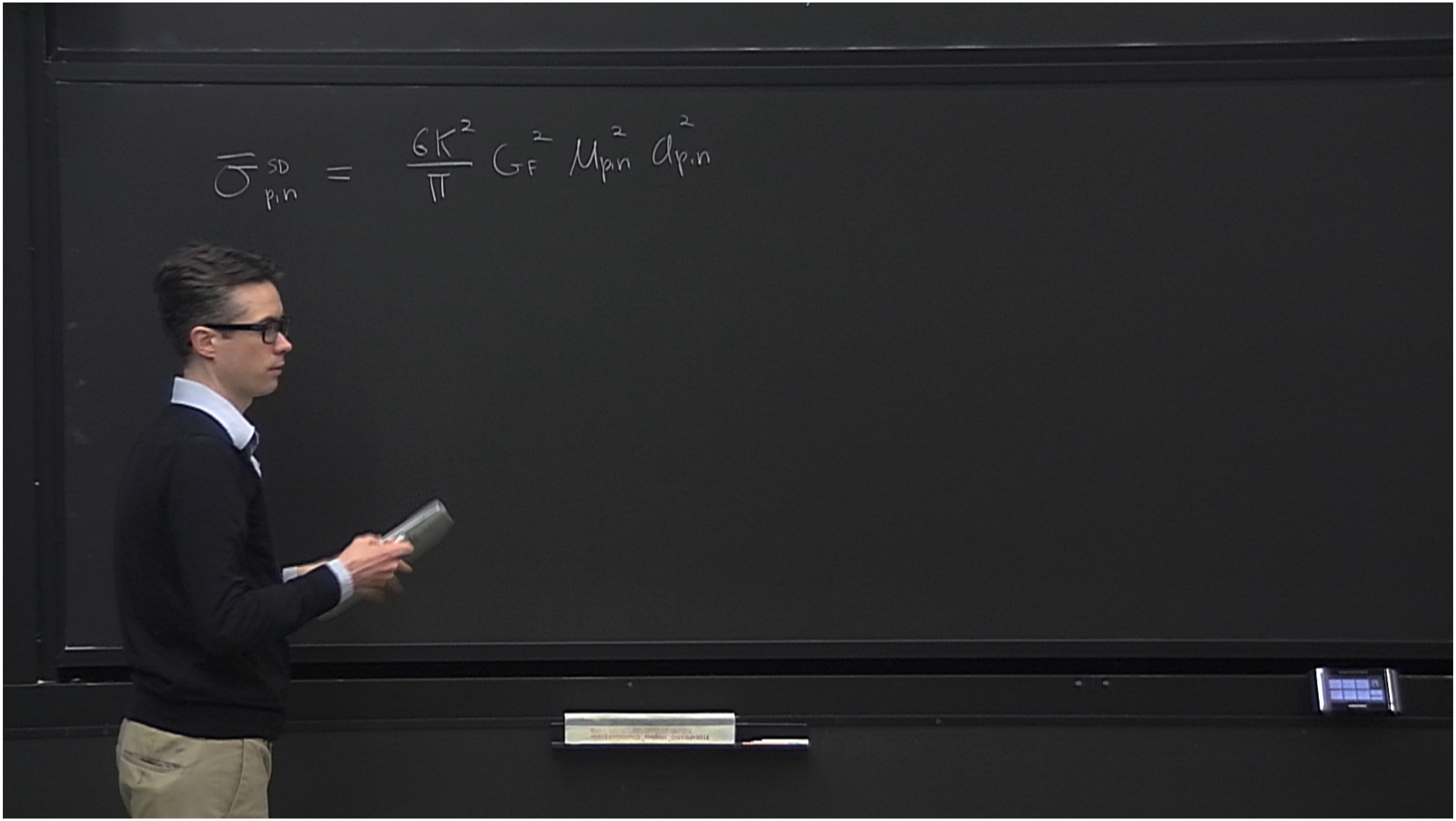
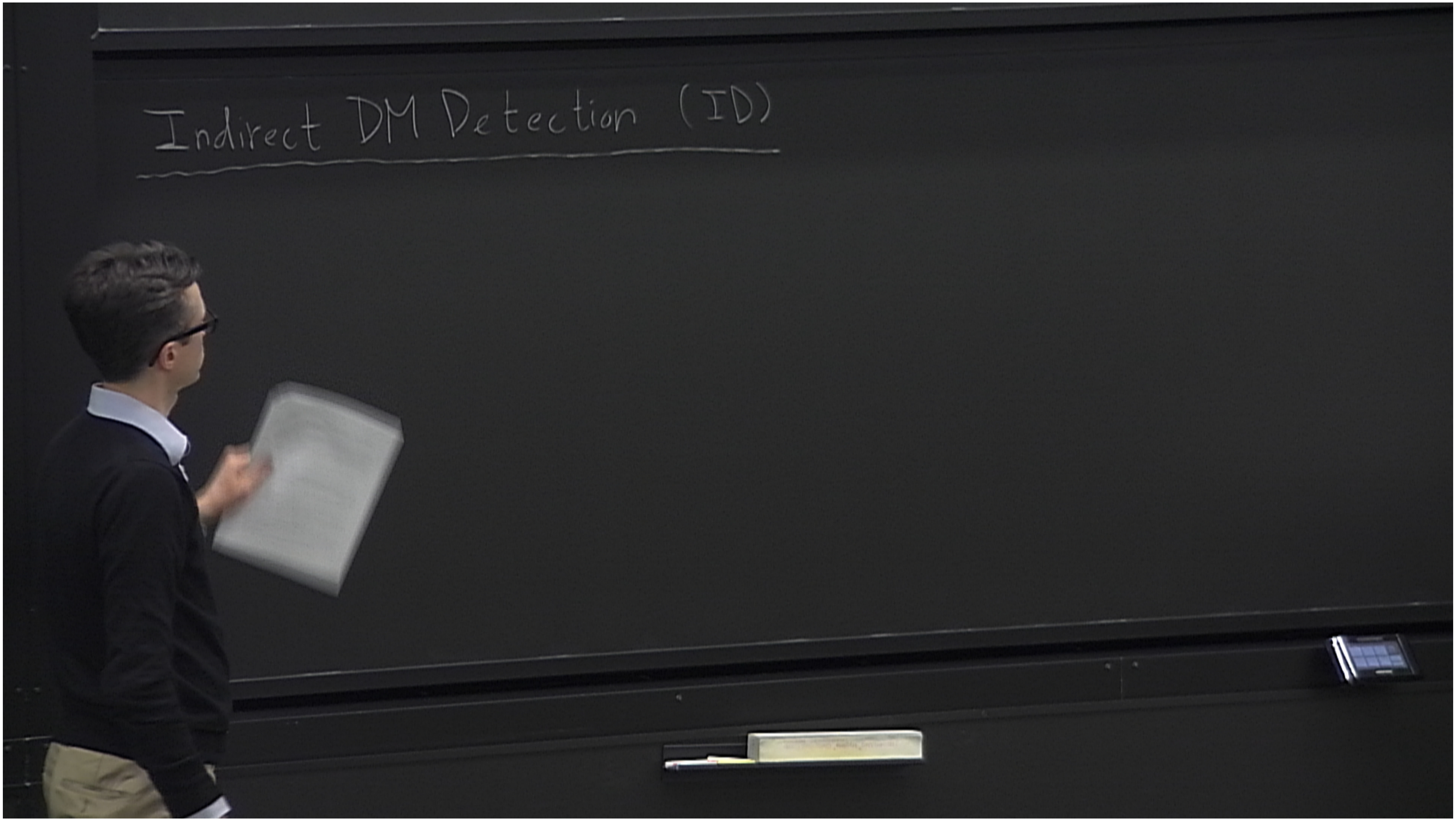
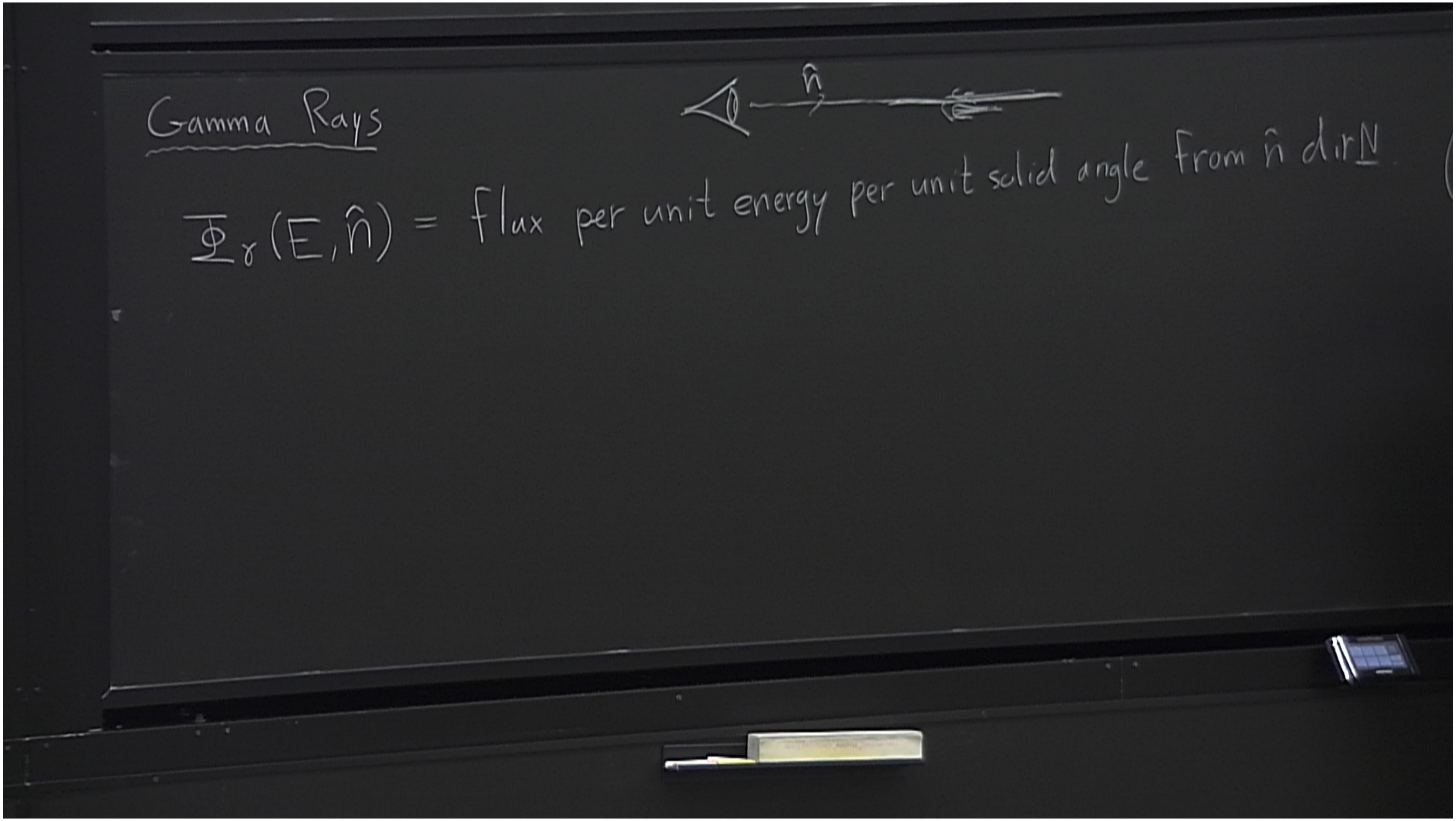
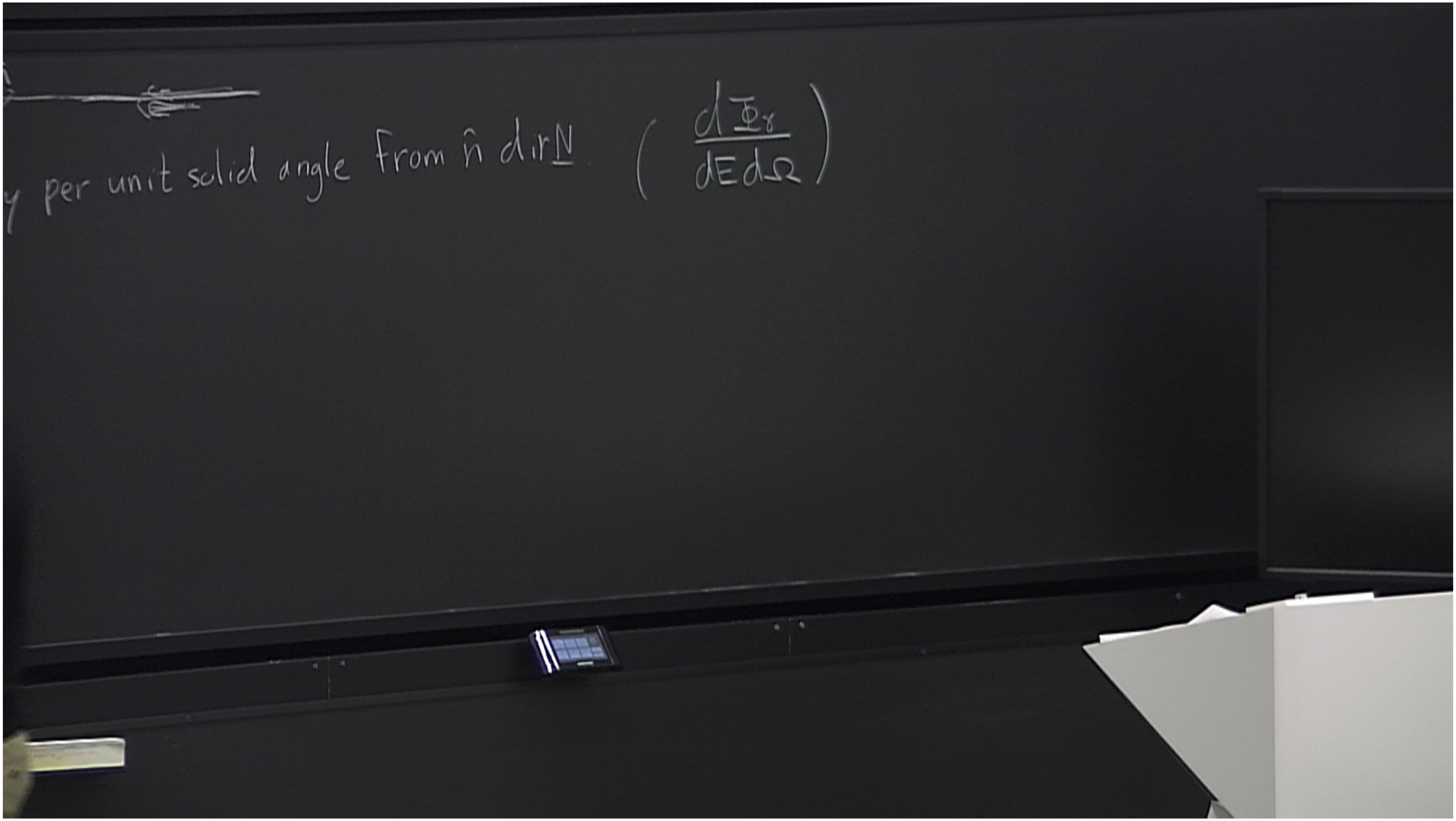
CRESST
XENON100
m_χ (GeV)
June 2
Dec 2
Sun
R
t
χ_1
χ_2
N

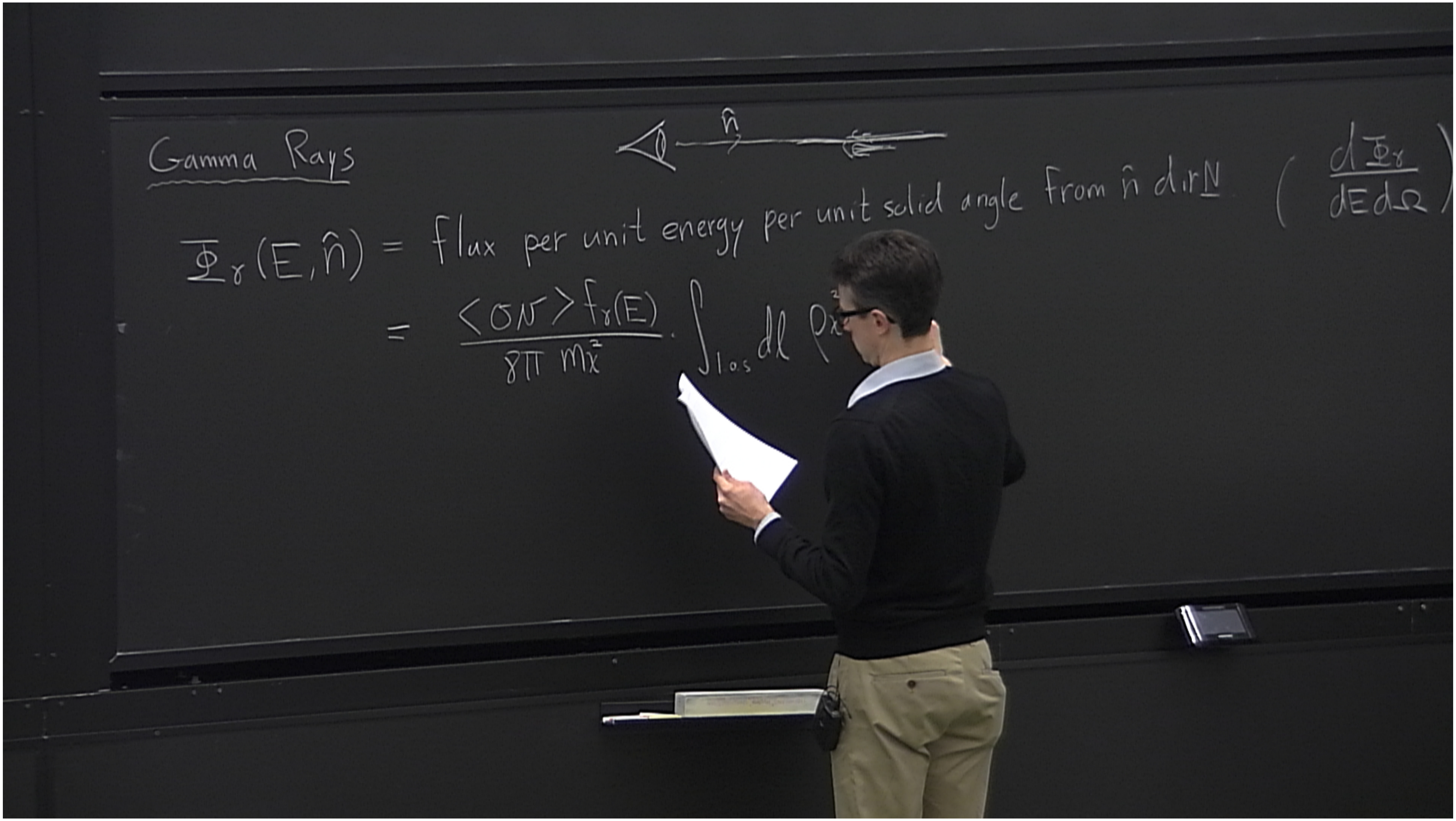

$\bar{\sigma}^{SD}_{p,n} = \frac{6K^2}{\pi} G_F^2 \mu_{p,n}^2 a_{p,n}^2$

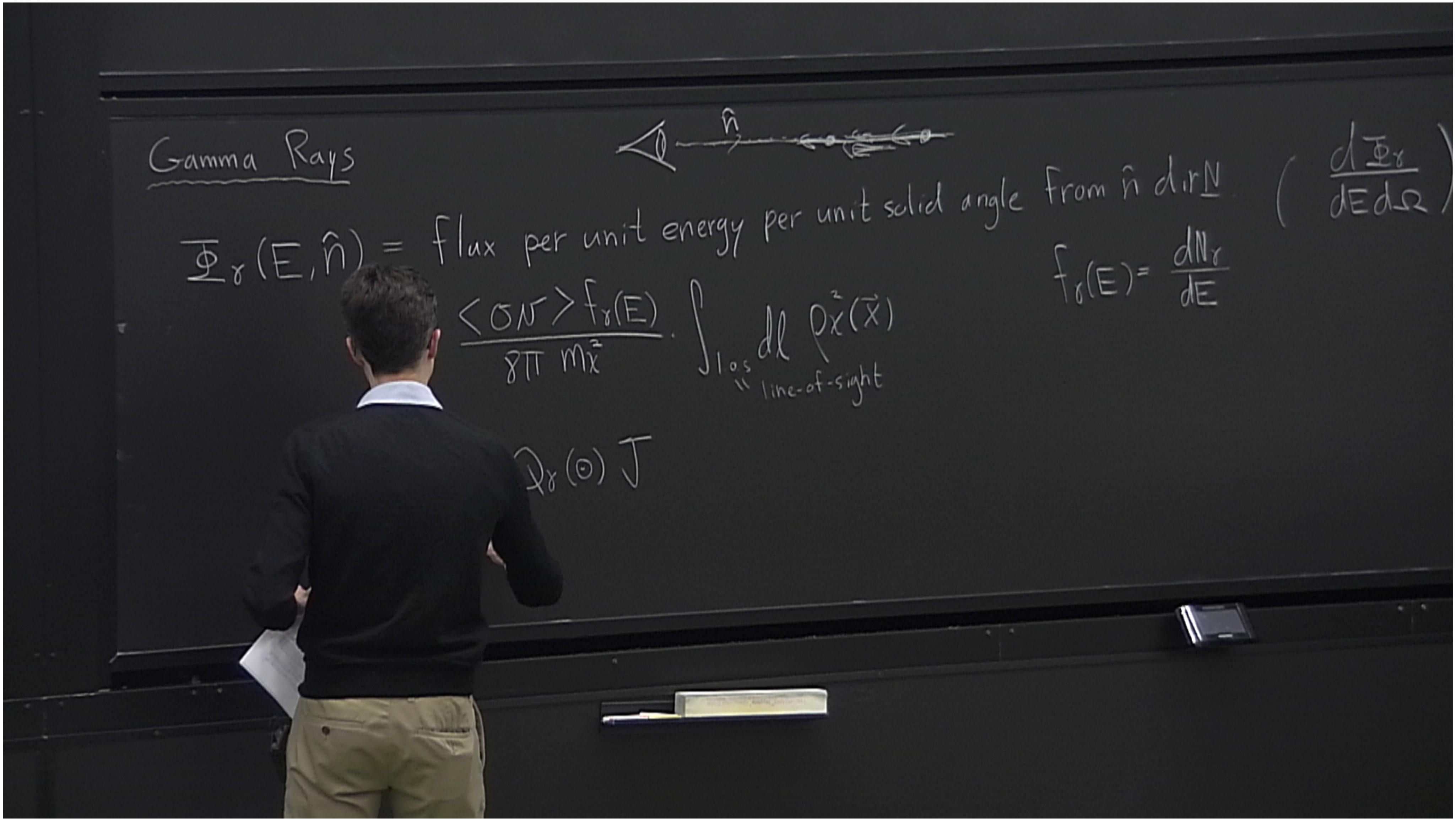

Indirect DM Detection (ID)

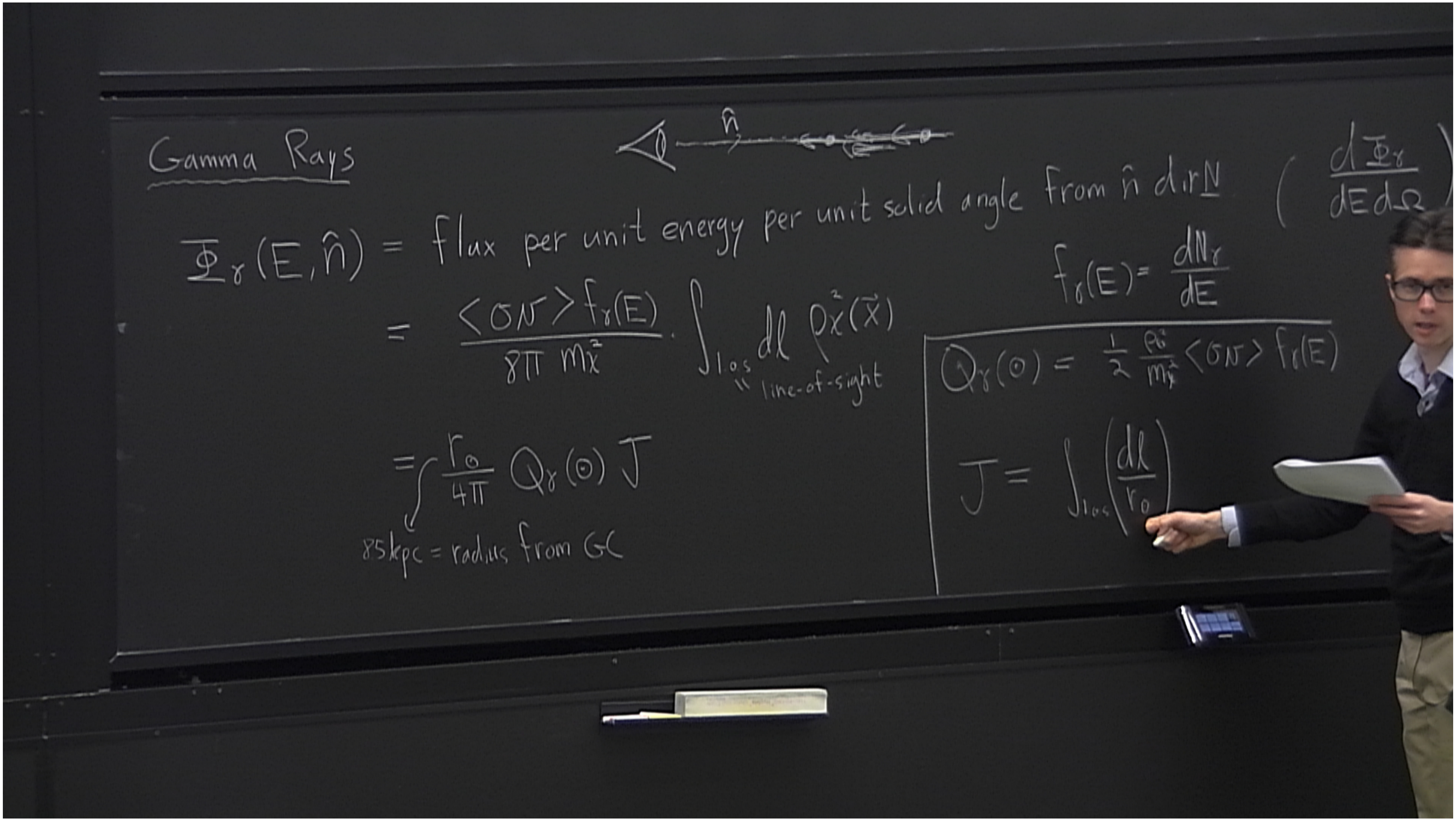

Gamma Rays


Gamma Rays
$\hat{n}$
$\Phi_\gamma(E, \hat{n})$ = flux per unit energy per unit solid angle from $\hat{n}$ dirN


y per unit solid angle from $\hat{n}$ dir$\underline{N}$
$\left(\frac{d\Phi_\gamma}{dE\,d\Omega} \right)$


Gamma Rays
$\hat{n}$
$\Phi_\gamma(E,\hat{n})$ = flux per unit energy per unit solid angle from $\hat{n}$ dirN $\left(\frac{d\Phi_\gamma}{dE\,d\Omega}\right)$
$= \frac{\langle \sigma v \rangle f_\gamma(E)}{8\pi m_\chi^2} \cdot \int_{l.o.s} dl\, \rho_\chi^2$


Gamma Rays
$\hat{n}$
$\Phi_\gamma(E,\hat{n})$ = flux per unit energy per unit solid angle from $\hat{n}$ dirN $\left(\frac{d\Phi_\gamma}{dE\,d\Omega}\right)$
$f_\gamma(E) = \frac{dN_\gamma}{dE}$
$\frac{\langle \sigma v \rangle f_\gamma(E)}{8\pi m_\chi^2} \cdot \int_{los} dl\, \rho_\chi^2(\vec{x})$
" line-of-sight
$\Phi_\gamma(\odot)\, J$


Gamma Rays
$\hat{n}$
$\Phi_\gamma(E,\hat{n})$ = flux per unit energy per unit solid angle from $\hat{n}$ dirN $\left(\frac{d\Phi_\gamma}{dE\,d\Omega}\right)$
$= \frac{\langle\sigma v\rangle f_\gamma(E)}{8\pi m_\chi^2}\cdot\int_{l.o.s} dl\, \rho_\chi^2(\vec{x})$
" line-of-sight
$f_\gamma(E) = \frac{dN_\gamma}{dE}$
$Q_\gamma(\odot) = \frac{1}{2}\frac{\rho_\odot^2}{m_\chi^2}\langle\sigma v\rangle f_\gamma(E)$
$J = \int_{l.o.s}\left(\frac{dl}{r_\odot}\right)$
$= \frac{r_\odot}{4\pi} Q_\gamma(\odot)\, J$
8.5 kpc = radius from GC

Gamma Rays

$\Phi_\gamma(E,\hat{n})$ = flux per unit energy per unit solid angle from $\hat{n}$ dirN $\left(\frac{d\Phi_\gamma}{dE\,d\Omega}\right)$

$$f_\gamma(E) = \frac{dN_\gamma}{dE}$$

$$= \frac{\langle \sigma v \rangle f_\gamma(E)}{8\pi\, m_\chi^2} \cdot \int_{l.o.s} dl\, \rho_\chi^2(\vec{x})$$

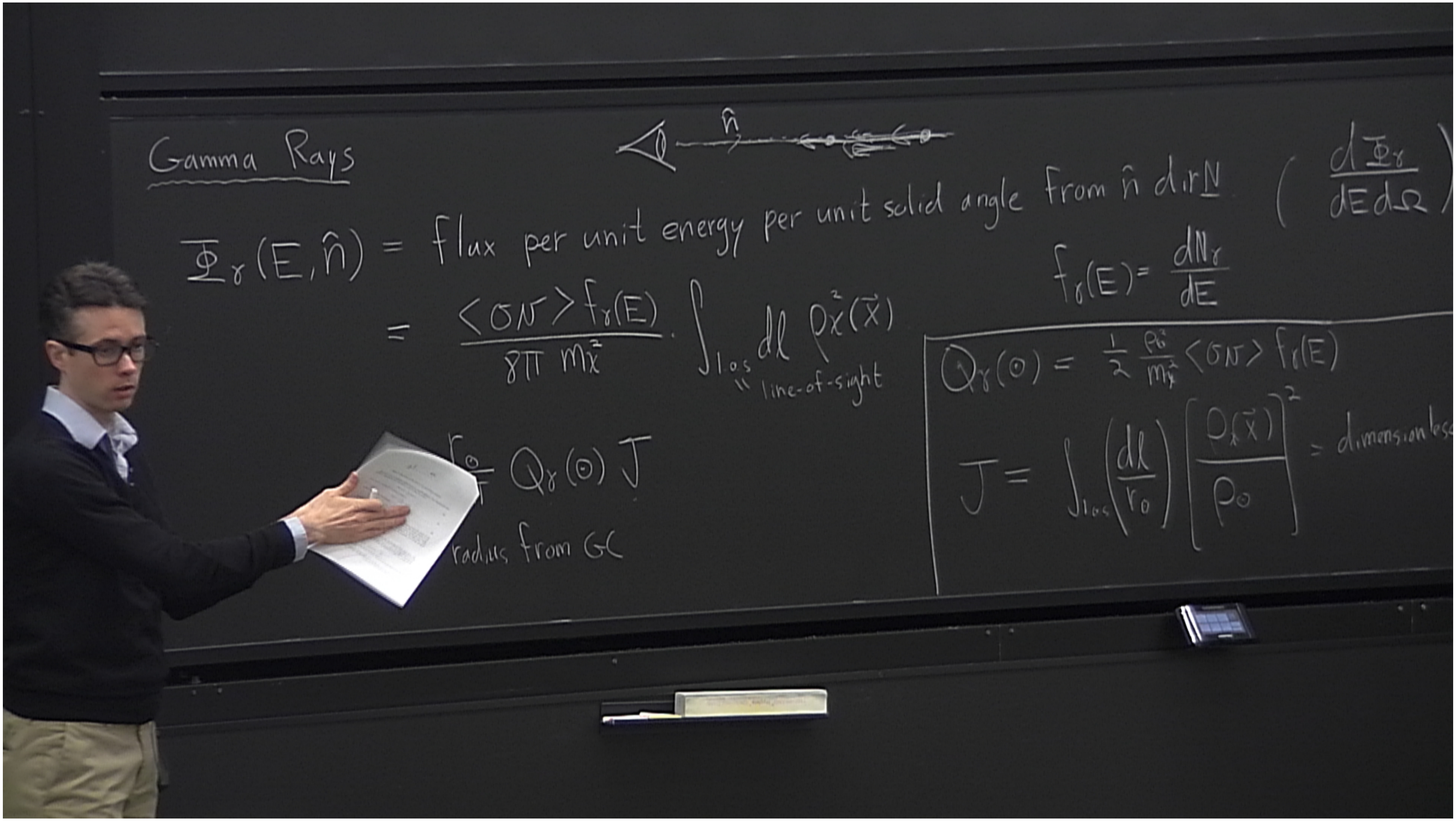
" line-of-sight

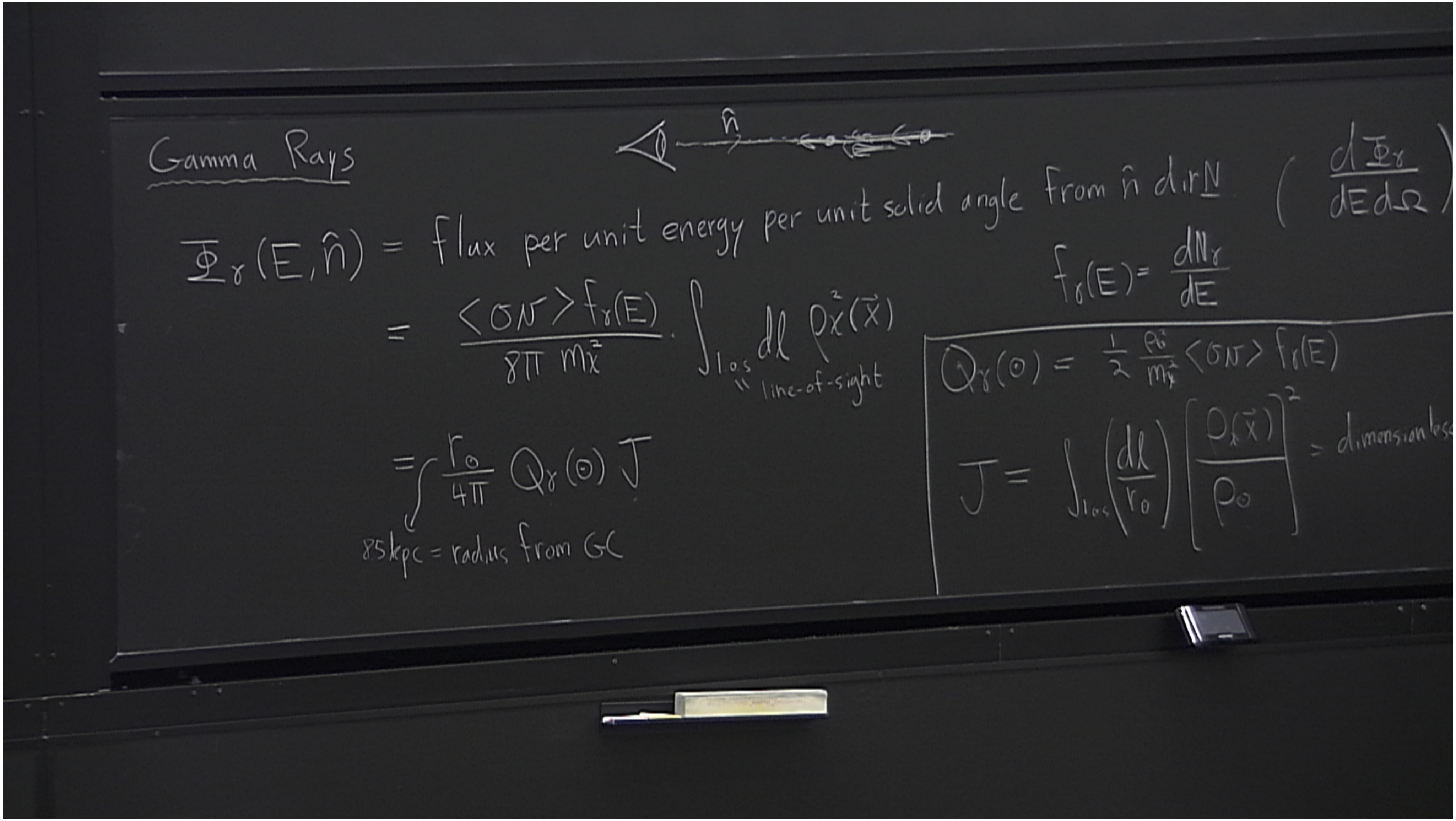
$$= \frac{r_\odot}{4\pi}\, Q_\gamma(\odot)\, J$$

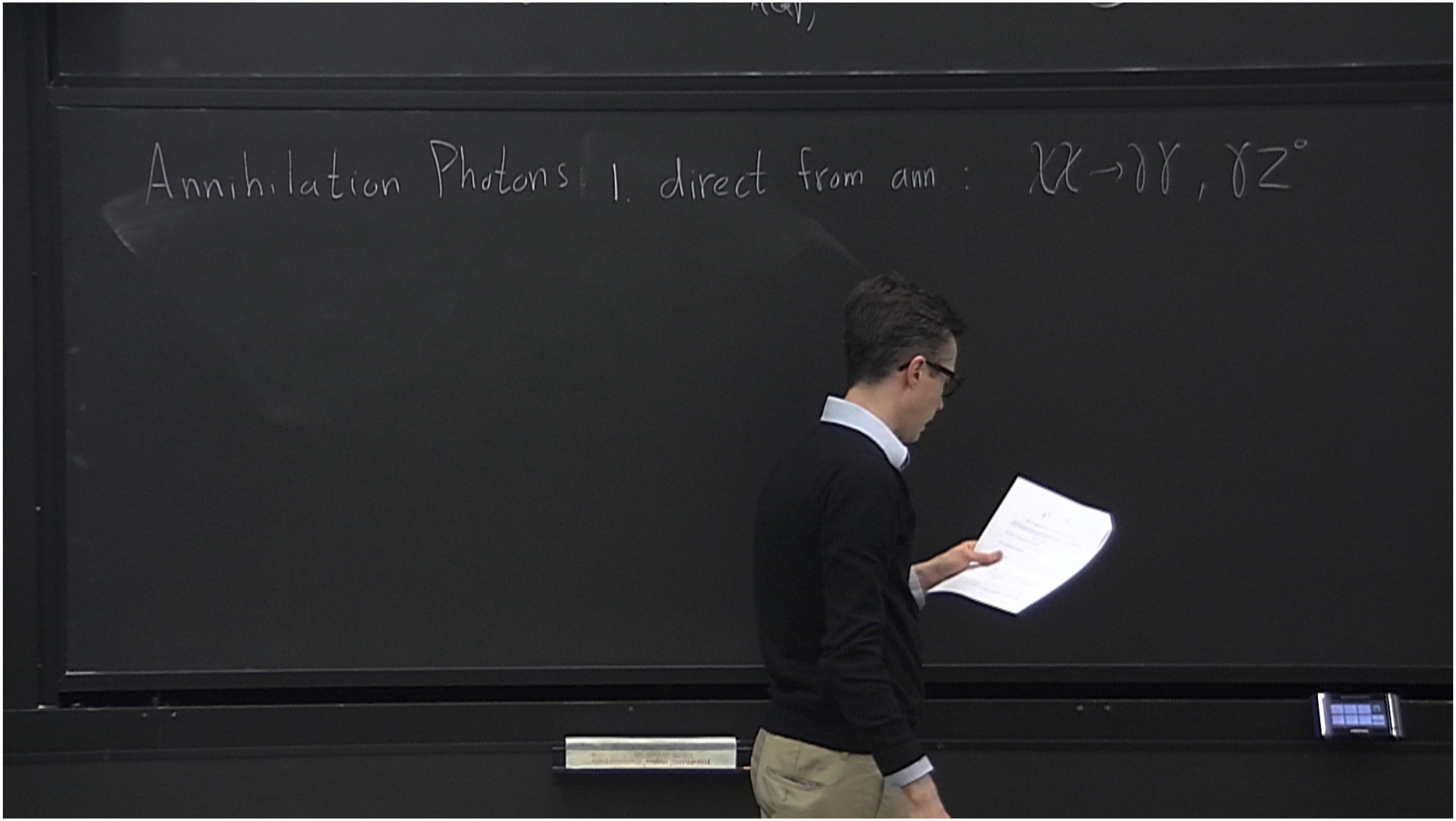
8.5 kpc = radius from GC

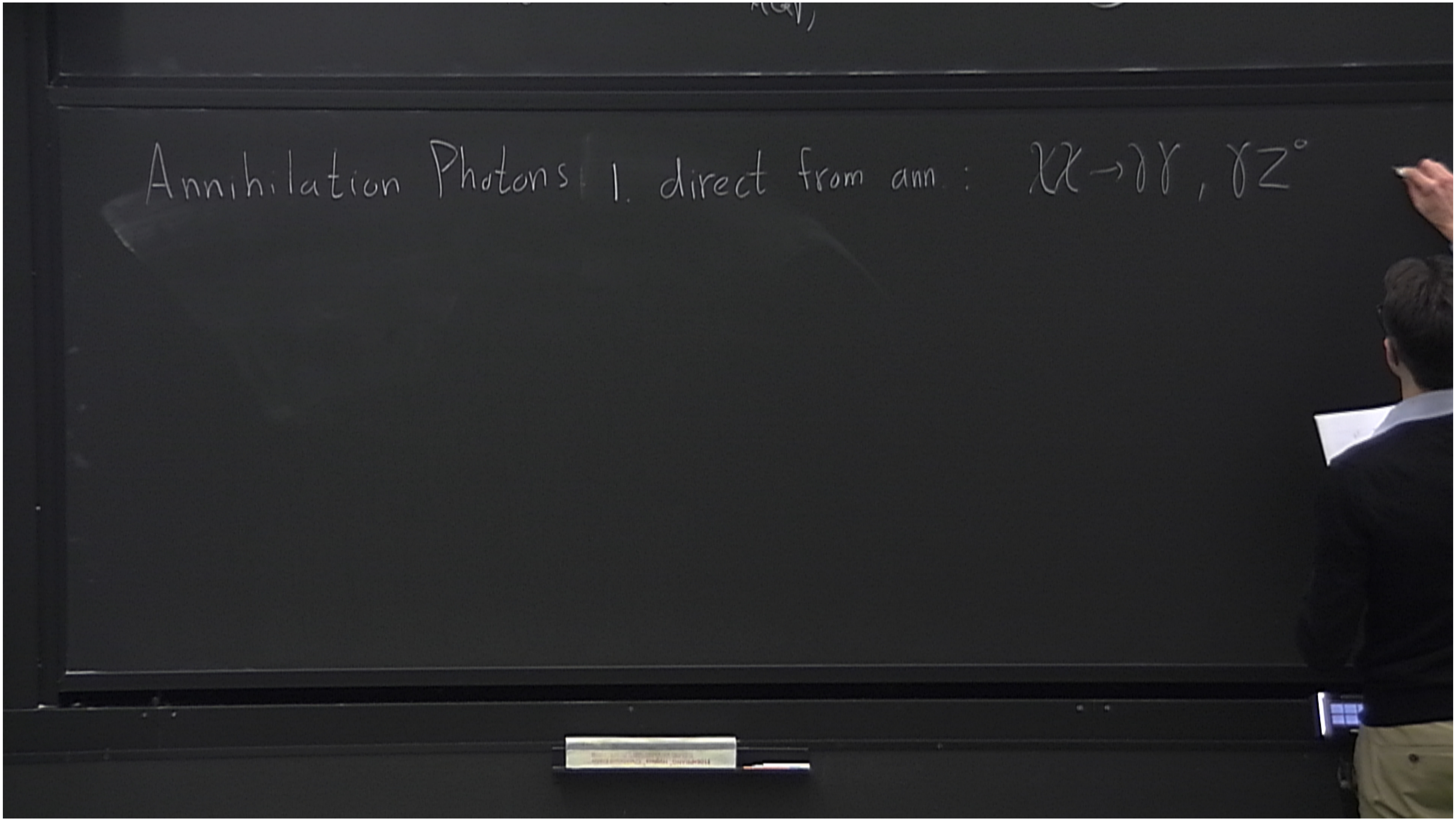
$$\boxed{Q_\gamma(\odot) = \frac{1}{2}\frac{\rho_\odot^2}{m_\chi^2}\langle \sigma v \rangle f_\gamma(E)}$$

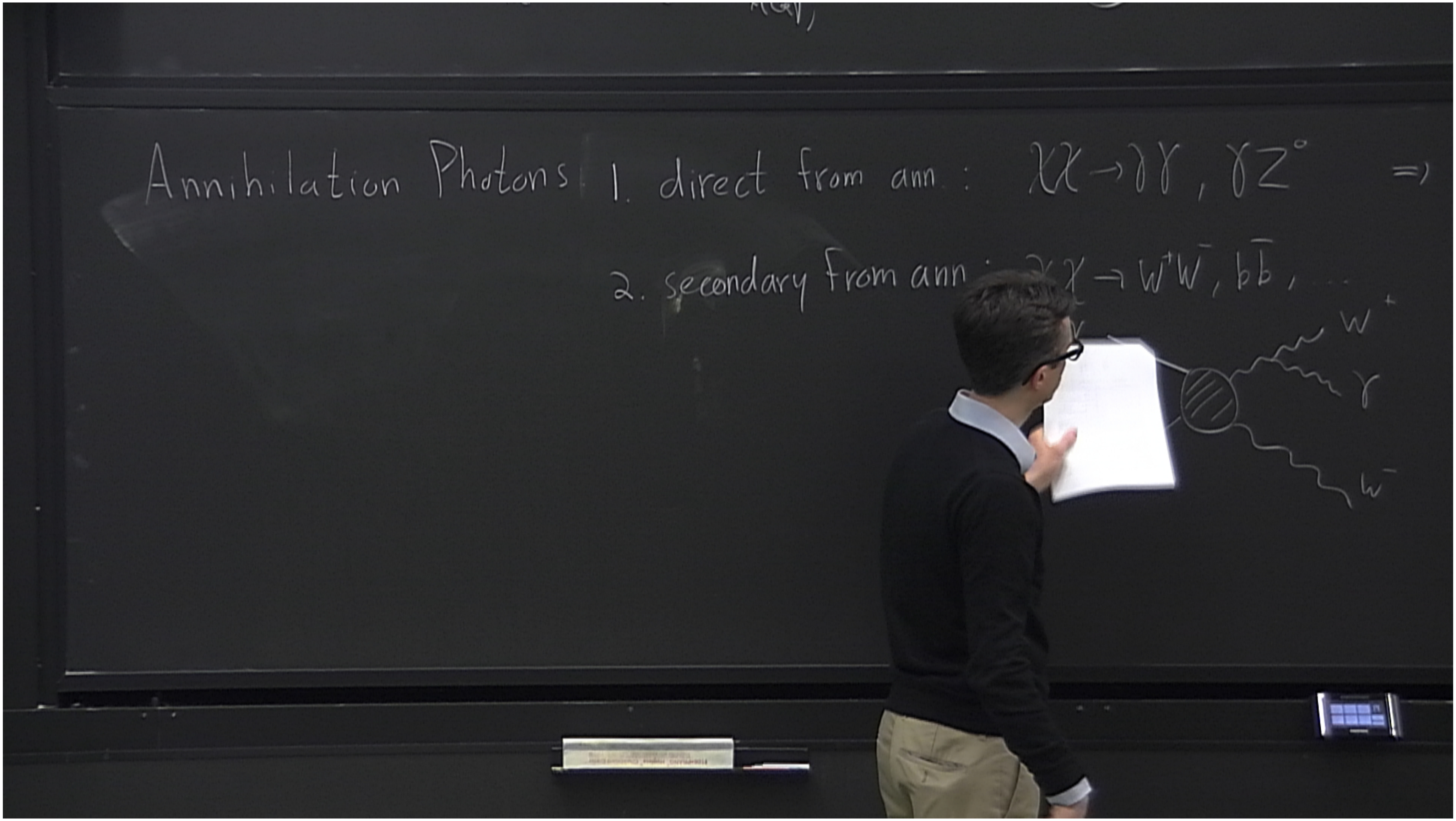
$$J = \int_{l.o.s}\left(\frac{dl}{r_\odot}\right)\left[\frac{\rho_\chi(\vec{x})}{\rho_\odot}\right]^2$$ = dimensionless


Gamma Rays
n̂
Φγ(E, n̂) = flux per unit energy per unit solid angle from n̂ dirN
dΦγ / dE dΩ
fγ(E) = dNγ / dE
= ⟨σv⟩ fγ(E) / 8π mχ² · ∫l.o.s dl ρχ²(x⃗)
" line-of-sight
Qγ(⊙) = ½ ρ⊙²/mχ² ⟨σv⟩ fγ(E)
J = ∫l.o.s (dl/r⊙) [ρχ(x⃗)/ρ⊙]² = dimensionless
r⊙ Qγ(⊙) J
radius from GC


Gamma Rays
$\hat{n}$
$\Phi_\gamma(E, \hat{n})$ = flux per unit energy per unit solid angle from $\hat{n}$ dir$\underline{N}$ $\left(\frac{d\Phi_\gamma}{dE\, d\Omega} \right)$
$= \frac{\langle \sigma v \rangle f_\gamma(E)}{8\pi m_\chi^2} \cdot \int_{l.o.s} dl\, \rho_\chi^2(\vec{x})$
" line-of-sight
$f_\gamma(E) = \frac{dN_\gamma}{dE}$
$Q_\gamma(\odot) = \frac{1}{2} \frac{\rho_\odot^2}{m_\chi^2} \langle \sigma v \rangle f_\gamma(E)$
$J = \int_{l.o.s} \left(\frac{dl}{r_\odot} \right) \left[\frac{\rho_\chi(\vec{x})}{\rho_\odot} \right]^2$ = dimensionless
$= \frac{r_\odot}{4\pi} Q_\gamma(\odot) J$
8.5 kpc = radius from GC

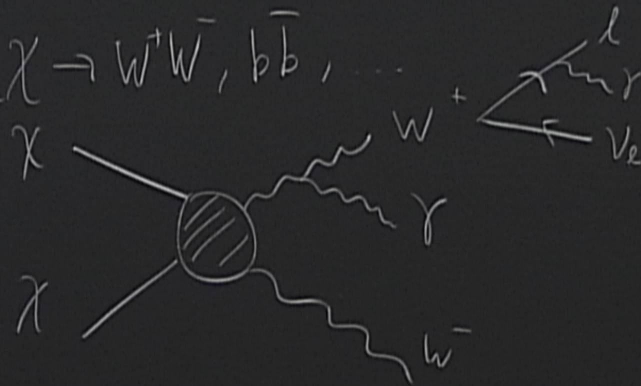

Annihilation Photons: 1. direct from ann: $\chi\chi \to \gamma\gamma, \gamma Z^0$


Annihilation Photons
1. direct from ann : $\chi\chi \to \gamma\gamma , \gamma Z^0$

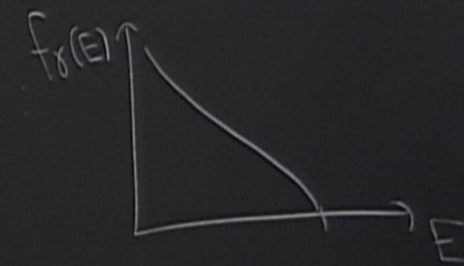

Annihilation Photons
1. direct from ann: $\chi\chi \to \gamma\gamma, \gamma Z^0$ ⇒
2. secondary from ann: $\chi\chi \to W^+W^-, b\bar{b}, \ldots$
W^+
γ
W^-

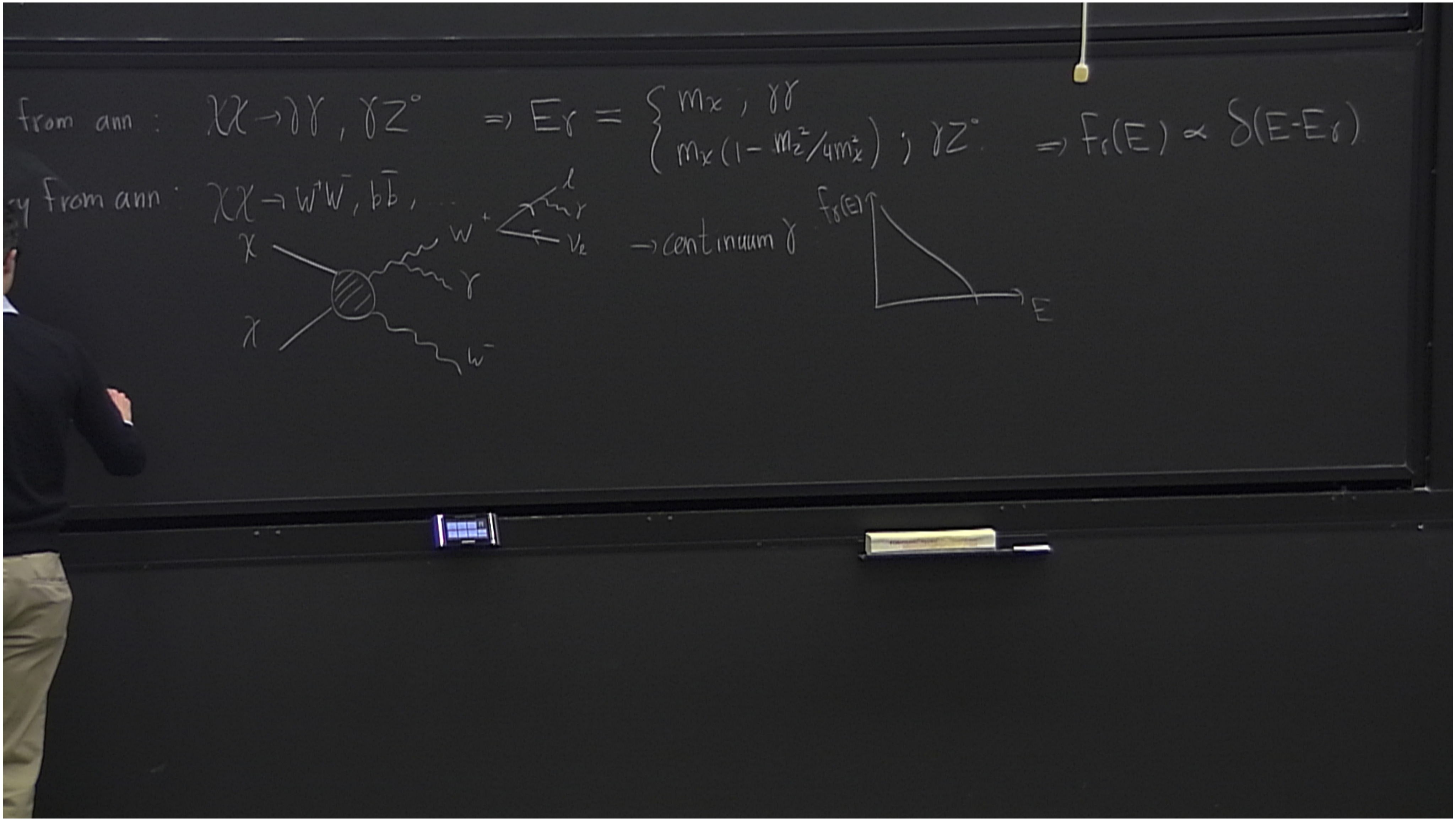
t from ann : $\chi\chi \to \gamma\gamma,\ \gamma Z^\circ \quad \Rightarrow E_\gamma = \begin{cases} m_\chi \ ; & \gamma\gamma \\ m_\chi\left(1 - m_Z^2/4m_\chi^2\right) \ ; & \gamma Z^\circ \end{cases} \quad \Rightarrow$

dary from ann : $\chi\chi \to W^+W^-,\ b\bar{b}, \ldots$



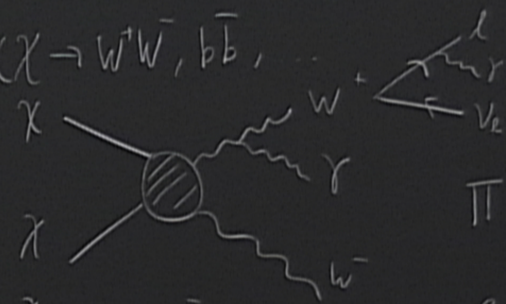
$\to$ continuum γ




from ann : $\chi\chi \to \gamma\gamma,\ \gamma Z^\circ \Rightarrow E_\gamma = \begin{cases} m_\chi \ ; \ \gamma\gamma \\ m_\chi(1 - m_Z^2/4m_\chi^2) \ ; \ \gamma Z^\circ \end{cases} \Rightarrow f_\gamma(E) \propto \delta(E - E_\gamma)$
y from ann : $\chi\chi \to W^+W^-, b\bar{b}, \ldots$
$\to$ continuum γ
$f_\gamma(E)$
E
χ
χ
W^+
W^-
γ
l
γ
ν_e

Annihilation Photons: 1. direct from ann : $\chi\chi \to \gamma\gamma, \gamma Z^0 \Rightarrow E_\gamma = \begin{cases} m_\chi ; \gamma\gamma \\ m_\chi(1 - m_Z^2/4m_\chi^2) \end{cases}$

2. secondary from ann : $\chi\chi \to W^+W^-, b\bar{b}, \ldots$

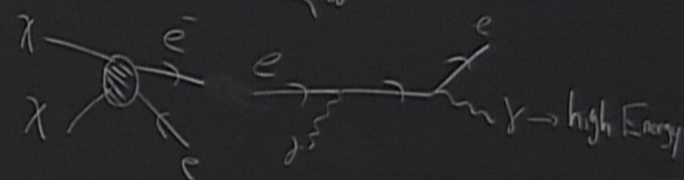


$\to$ continuum γ

$\pi^0 \to \gamma\gamma$

$f_\gamma(E)$

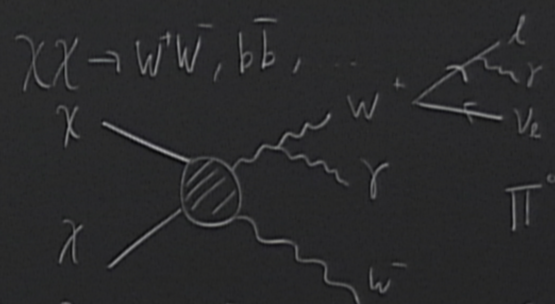
3. Inverse Compton (IC)



$\gamma \to$ high Energy

Annihilation Photons: 1. direct from ann: $\chi\chi \to \gamma\gamma, \gamma Z^0$ $\Rightarrow E_\gamma = \begin{cases} m_\chi \,; \gamma\gamma \\ m_\chi(1 - m_Z^2/4m_\chi^2) \end{cases}$

2. secondary from ann: $\chi\chi \to W^+W^-, b\bar{b}, \ldots$

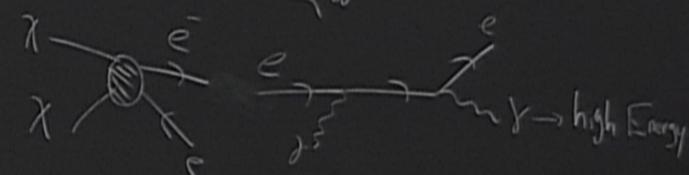


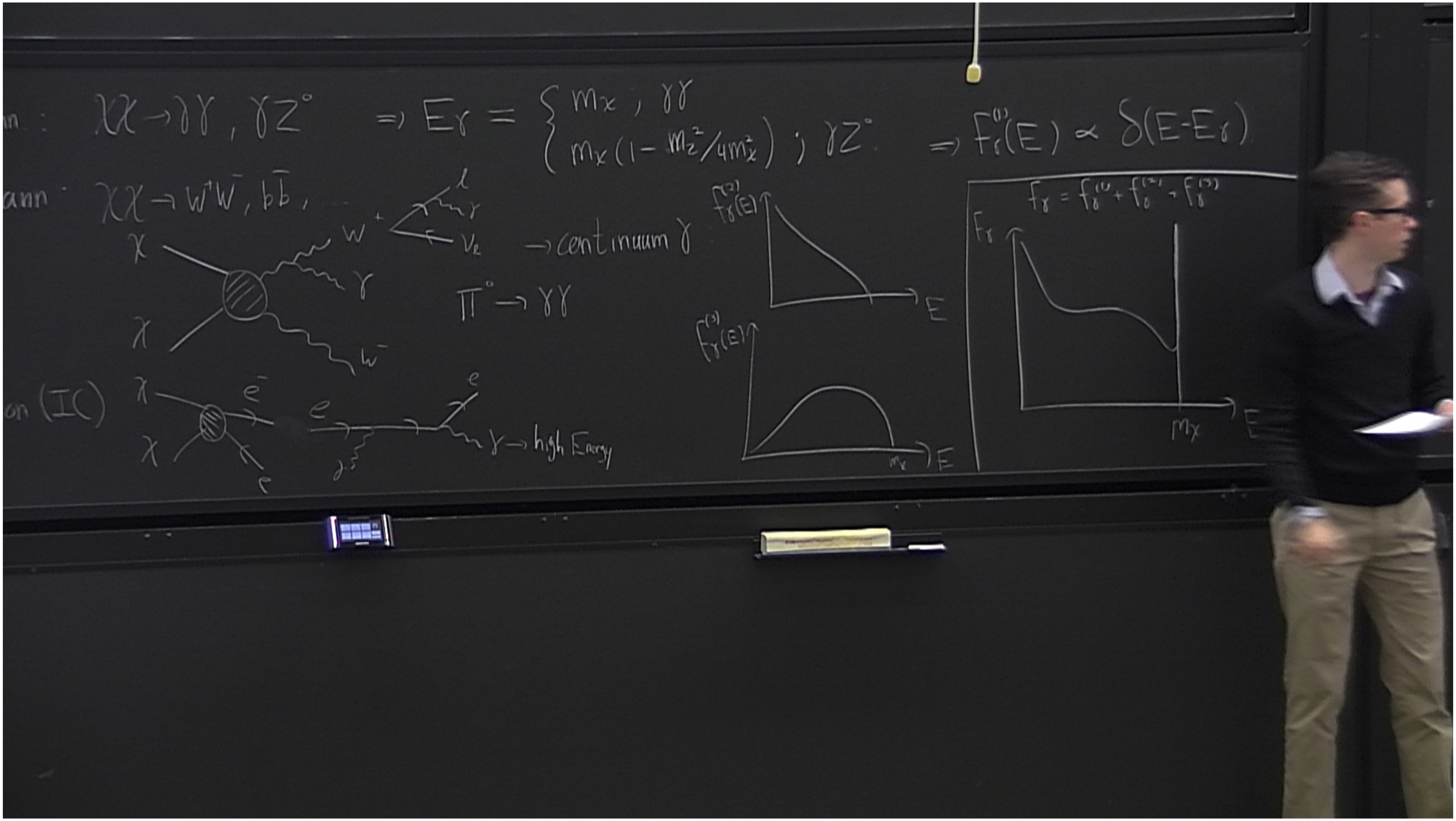
$\to$ continuum γ

$\pi^0 \to \gamma\gamma$

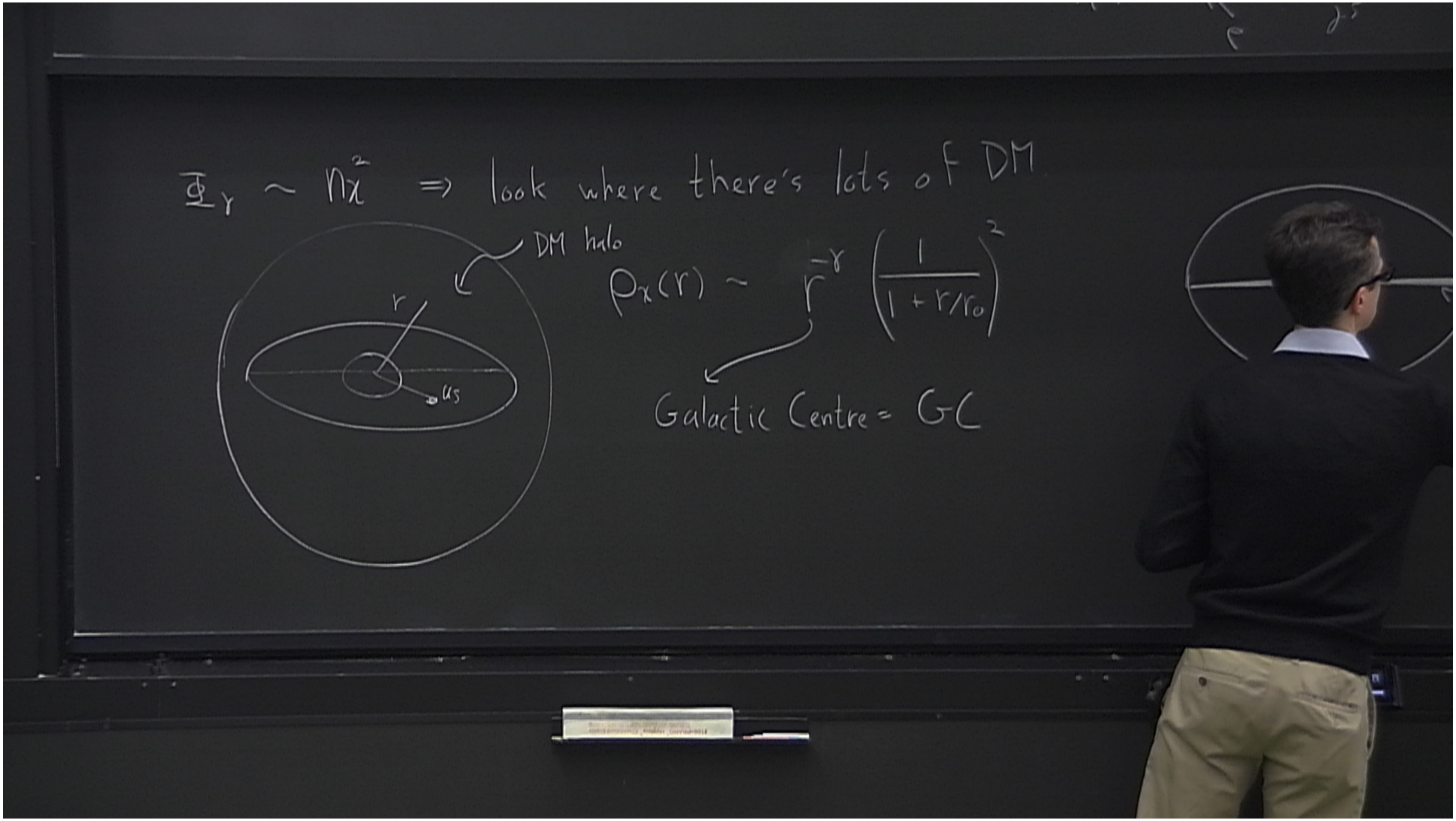
$f_\gamma(E)$

3. Inverse Compton (IC)





$\chi\chi \to \gamma\gamma,\ \gamma Z^0 \Rightarrow E_\gamma = \begin{cases} m_\chi ; \gamma\gamma \\ m_\chi(1 - m_Z^2/4m_\chi^2) ; \gamma Z^0 \end{cases} \Rightarrow f_\gamma^{(1)}(E) \propto \delta(E - E_\gamma)$
ann $\chi\chi \to W^+W^-, b\bar{b},$
$\to$ continuum γ
$\pi^0 \to \gamma\gamma$
(IC)
$\gamma \to$ high Energy
$f_\gamma^{(2)}(E)$
$f_\gamma^{(3)}(E)$
$f_\gamma = f_\gamma^{(1)} + f_\gamma^{(2)} + f_\gamma^{(3)}$
F_γ
m_χ
E

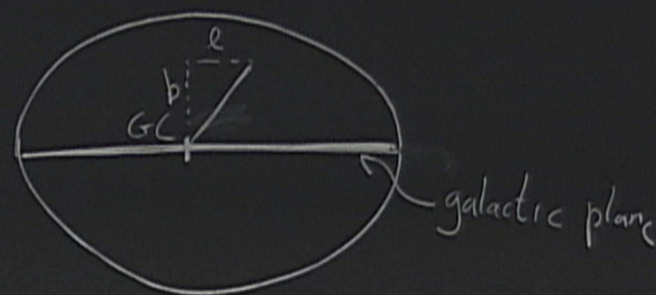

$\Phi_\gamma \sim n_\chi^2 \Rightarrow$ look where there's lots of DM
DM halo
r
us
$\rho_\chi(r) \sim r^{-\gamma}\left(\frac{1}{1+r/r_0}\right)^2$
Galactic Centre = GC

k where there's lots of DM

DM halo

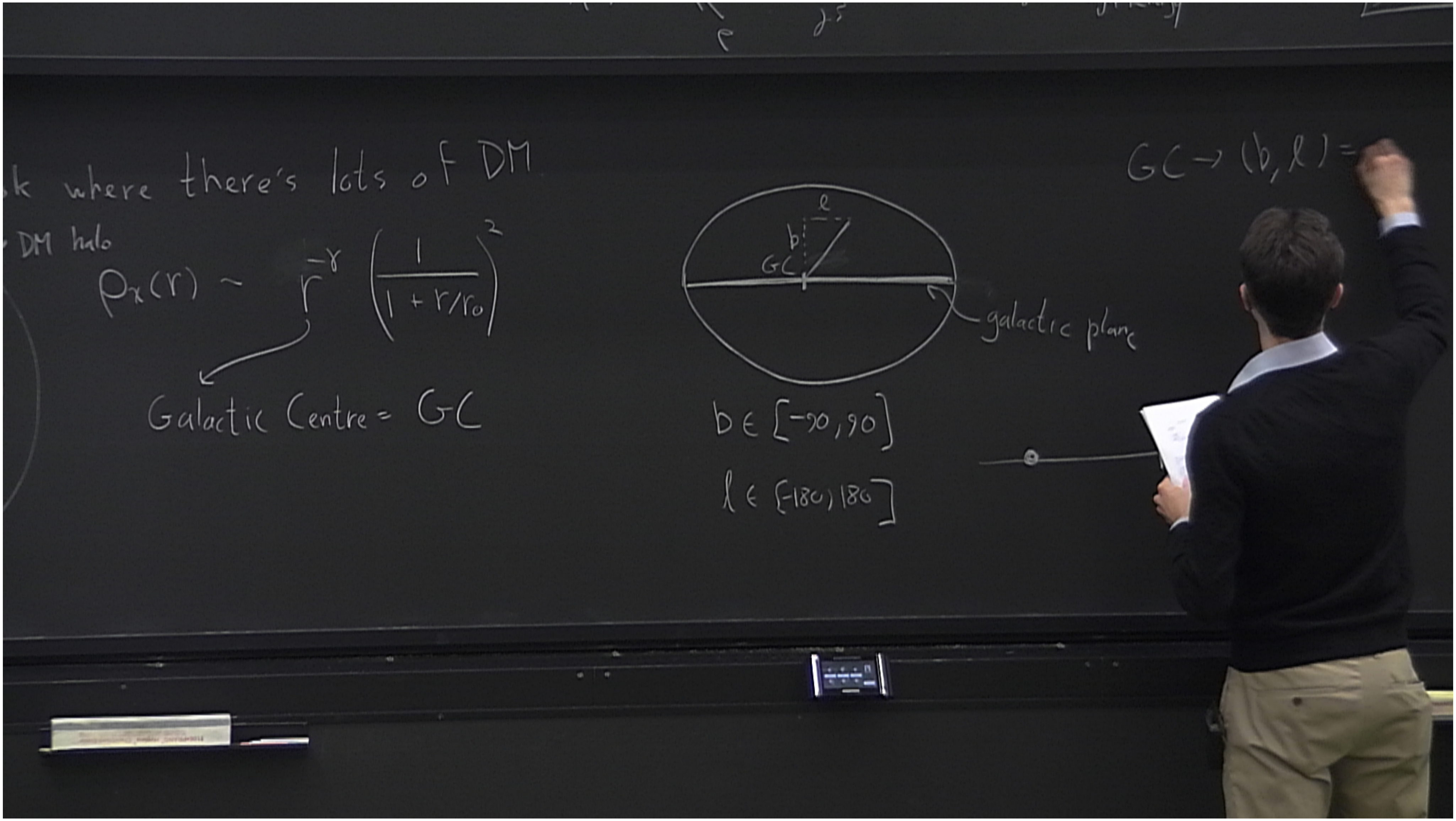
$$\rho_\chi(r) \sim r^{-\gamma}\left(\frac{1}{1+r/r_0}\right)^2$$

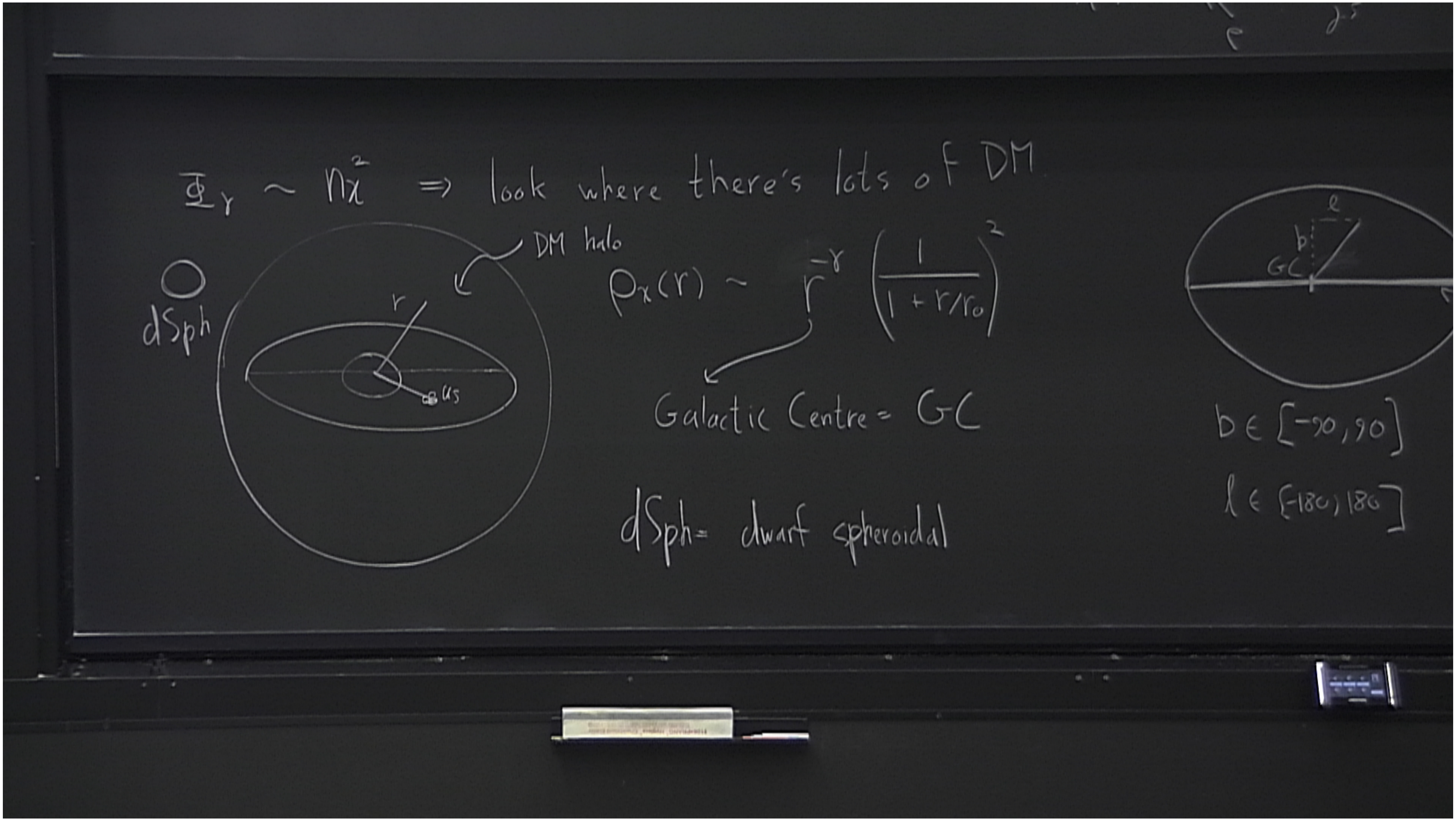
Galactic Centre = GC

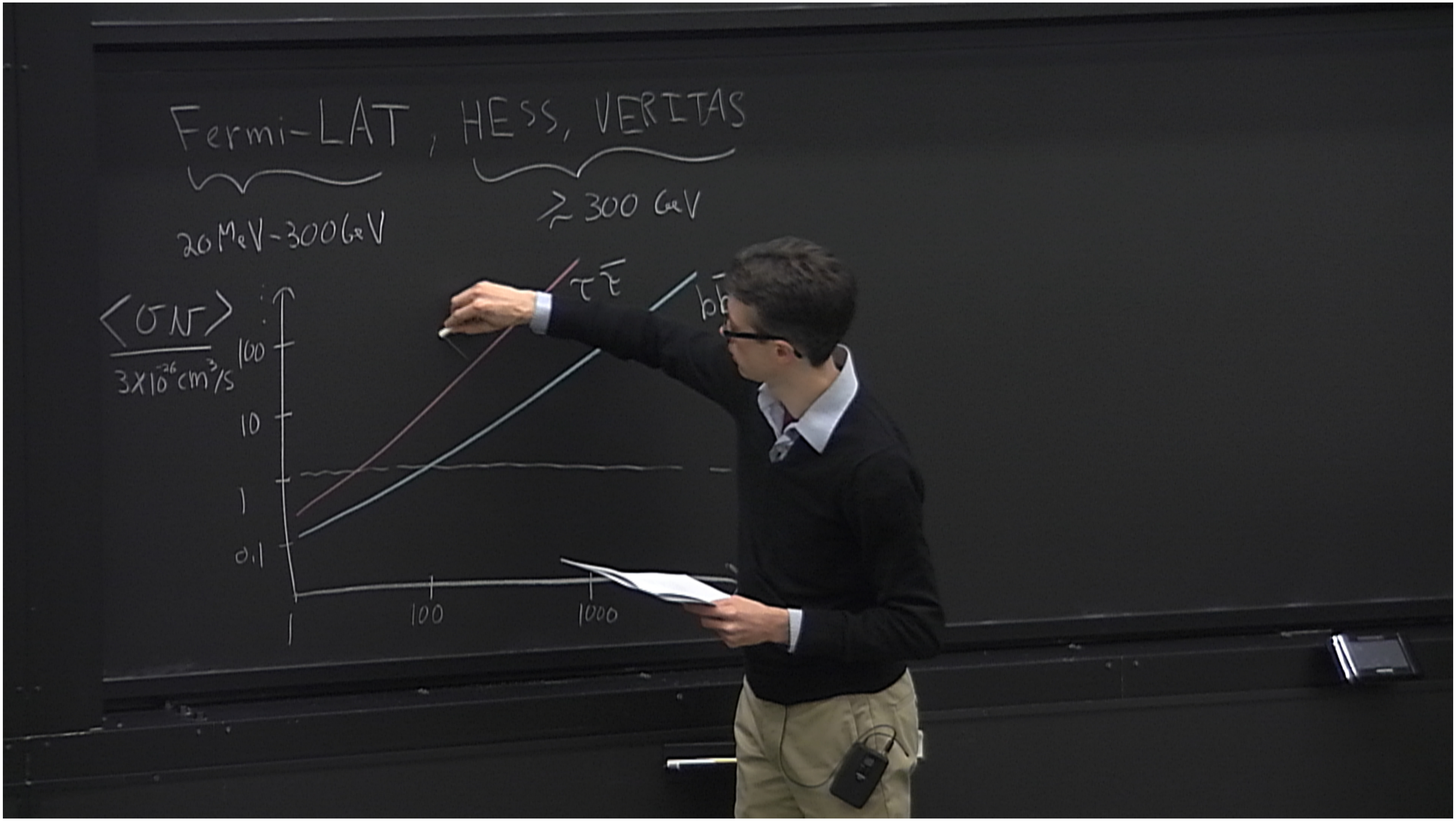


$b \in [-90, 90]$

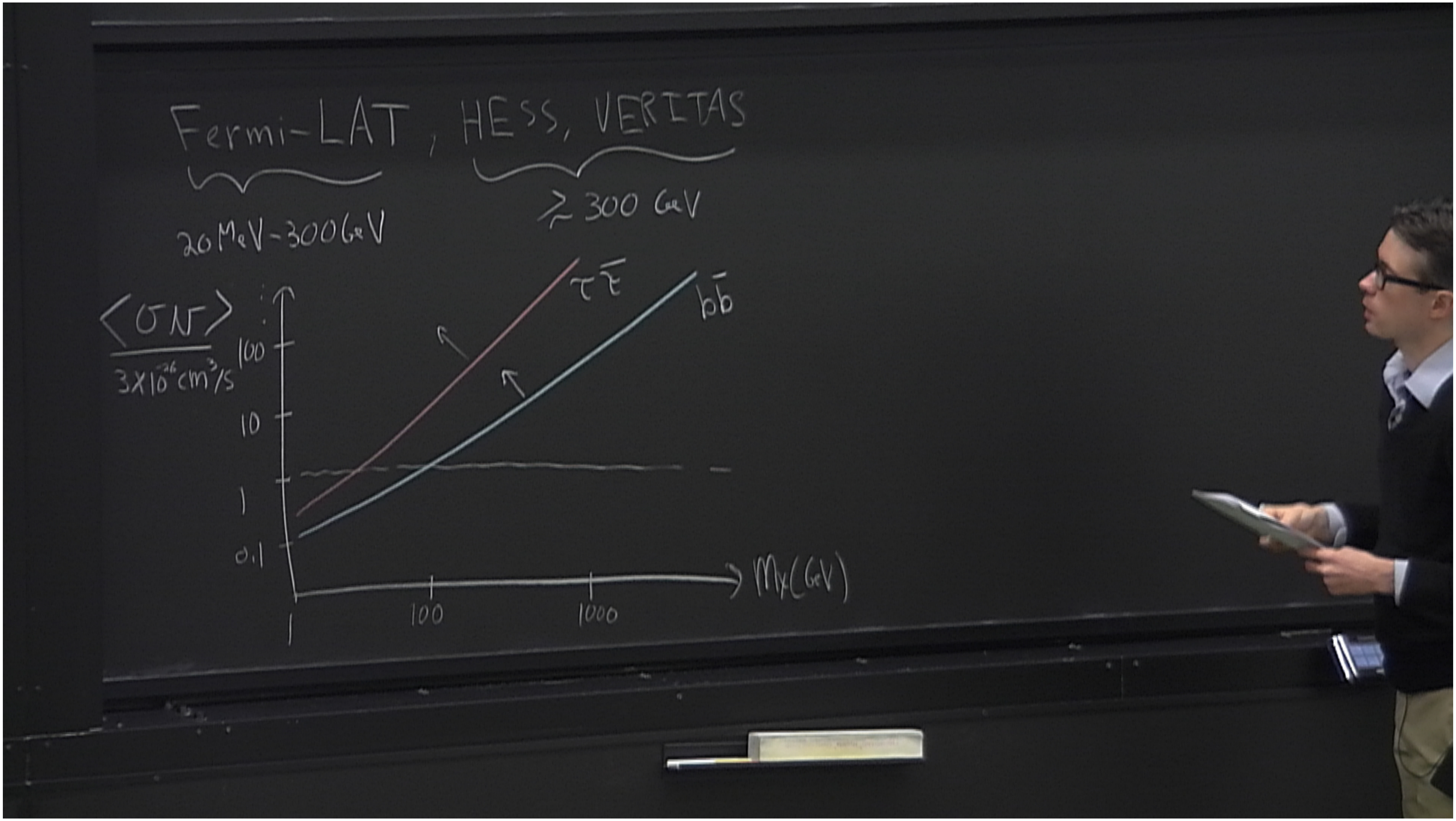
$l \in [-180, 180]$


k where there's lots of DM
DM halo
$\rho_\chi(r) \sim r^{-\gamma}\left(\frac{1}{1+r/r_0}\right)^2$
Galactic Centre = GC
GC
b
ℓ
galactic plane
$b \in [-90, 90]$
$\ell \in [-180, 180]$
$GC \to (b, \ell) =$

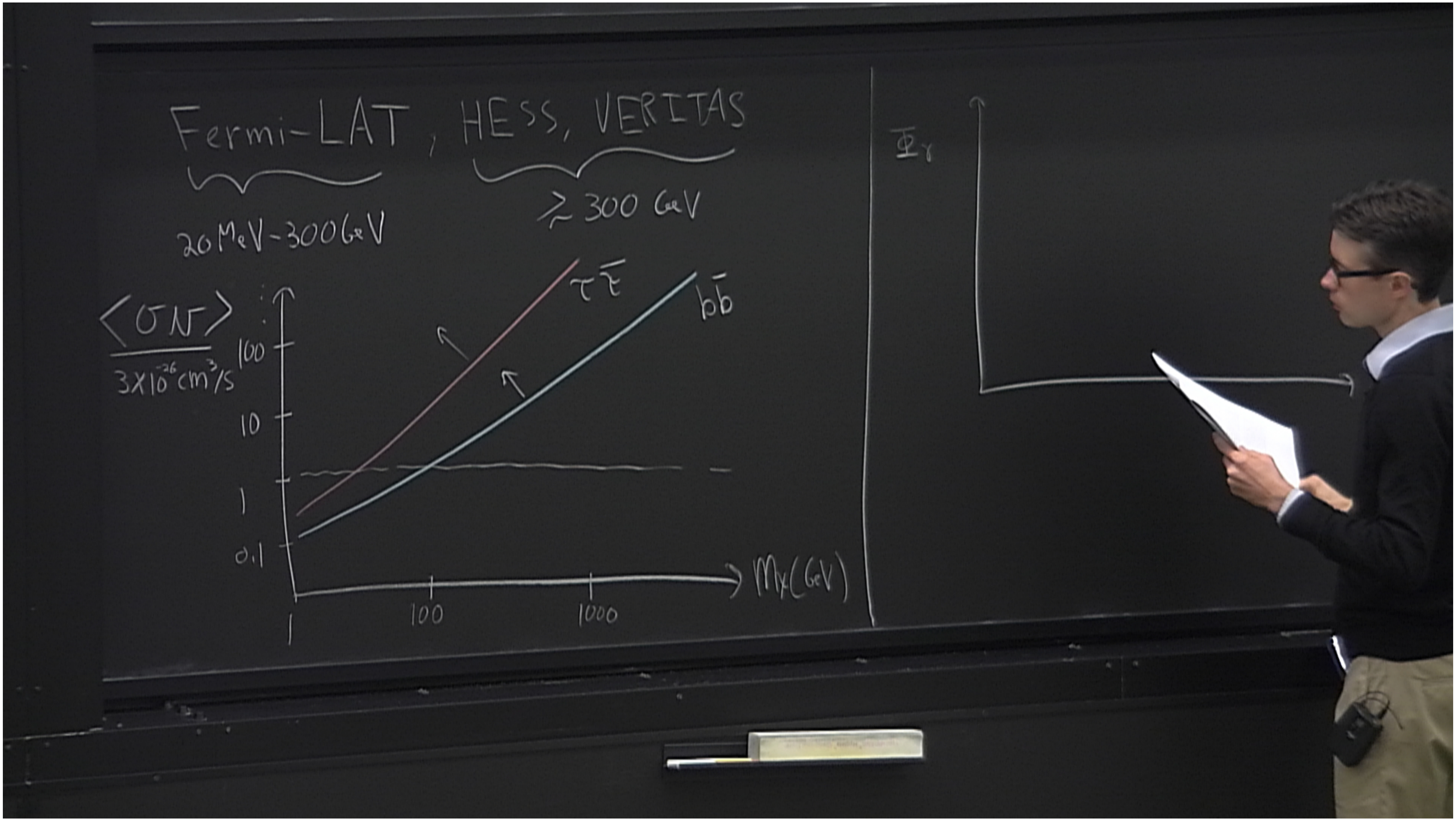

Φ_γ ~ n_χ^2 ⇒ look where there's lots of DM
DM halo
dSph
r
us
ρ_χ(r) ~ r^{-γ} (1 / (1 + r/r_0))^2
Galactic Centre = GC
dSph = dwarf spheroidal
l
b
GC
b ∈ [-90, 90]
l ∈ [-180, 180]

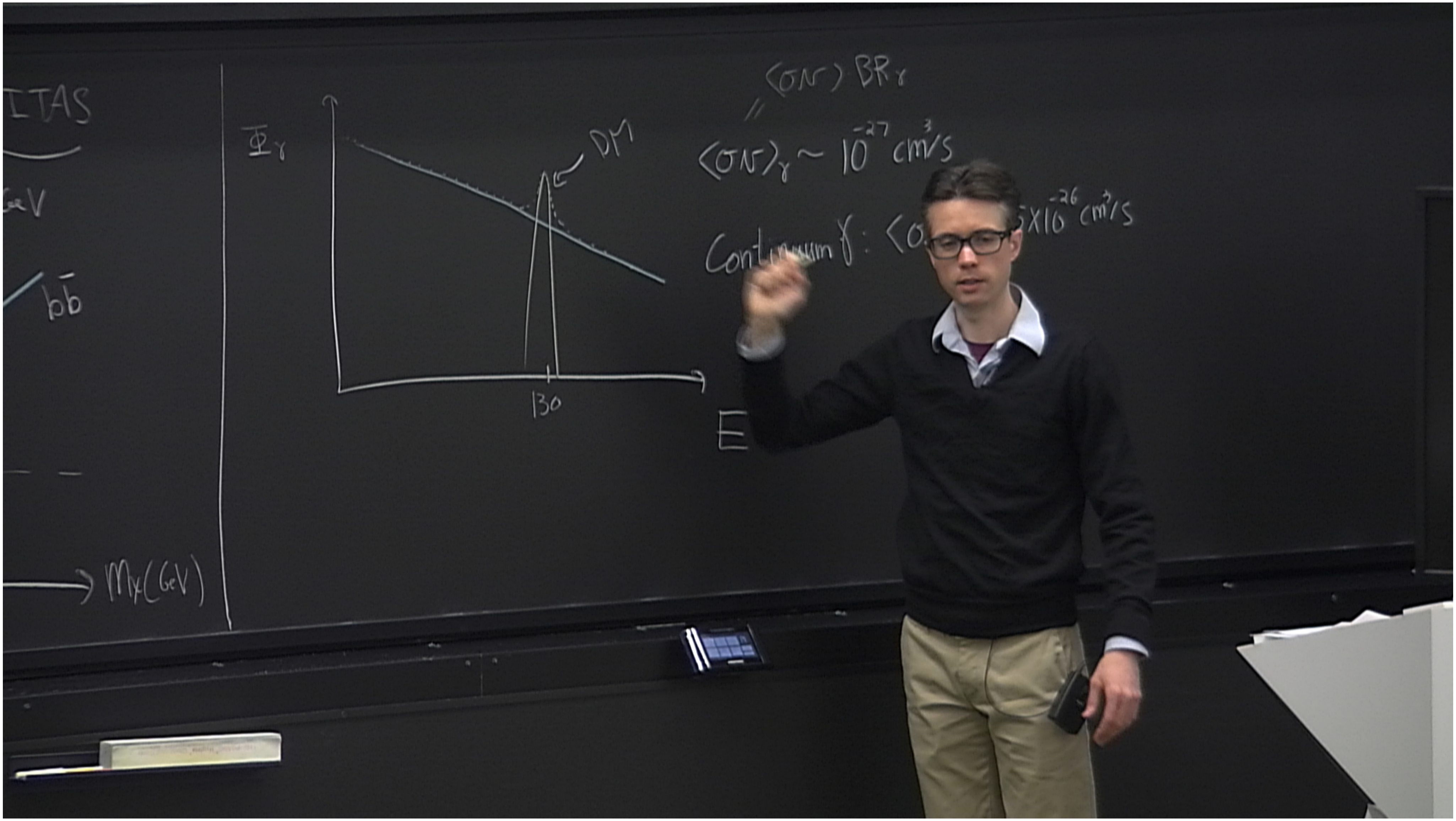


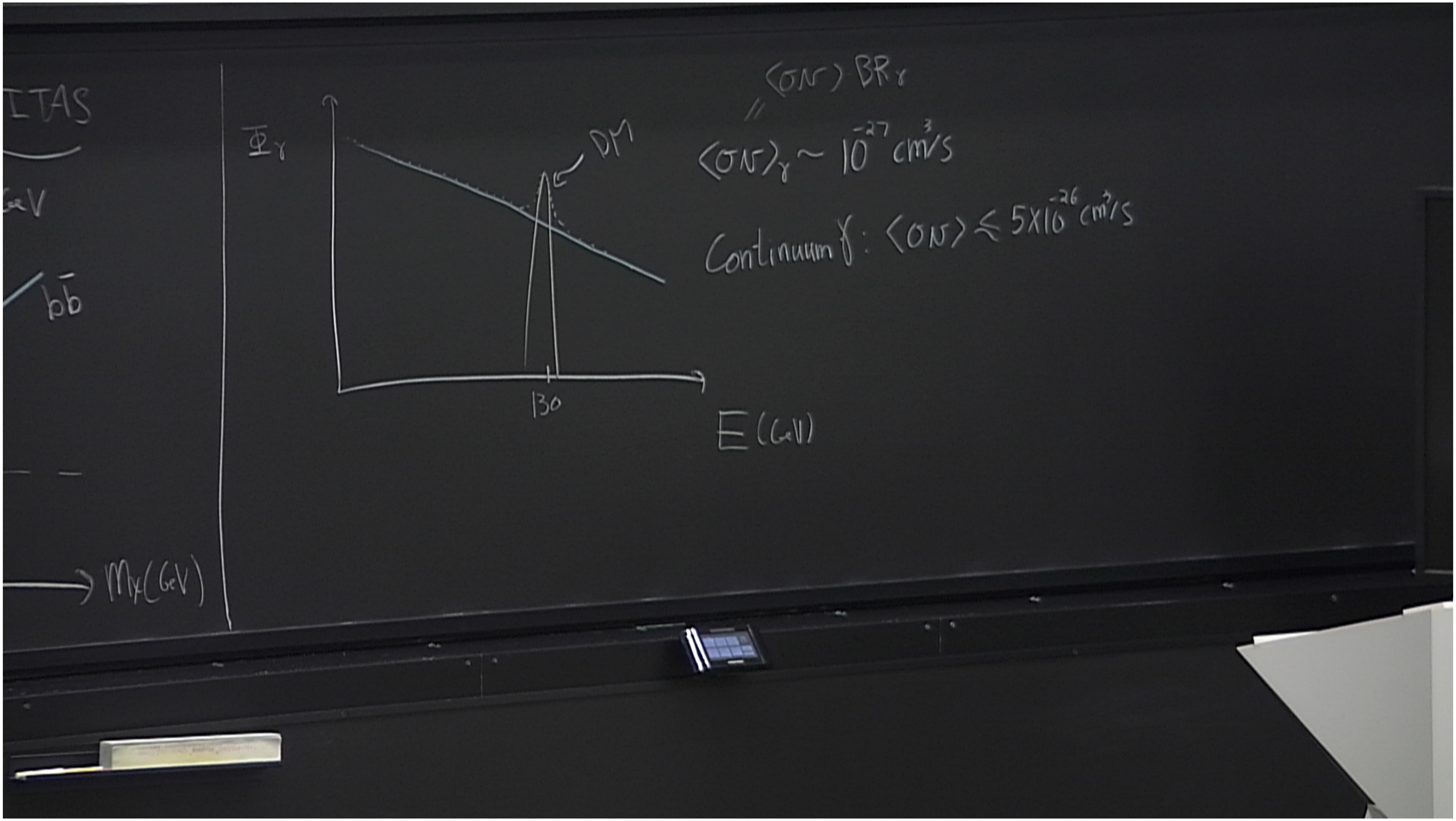
Fermi-LAT, HESS, VERITAS
20 MeV - 300 GeV
≳ 300 GeV
$\tau\bar{\tau}$
$b\bar{b}$
$\frac{\langle \sigma v \rangle}{3\times10^{-26}\,cm^3/s}$
100
10
1
0.1
1
100
1000

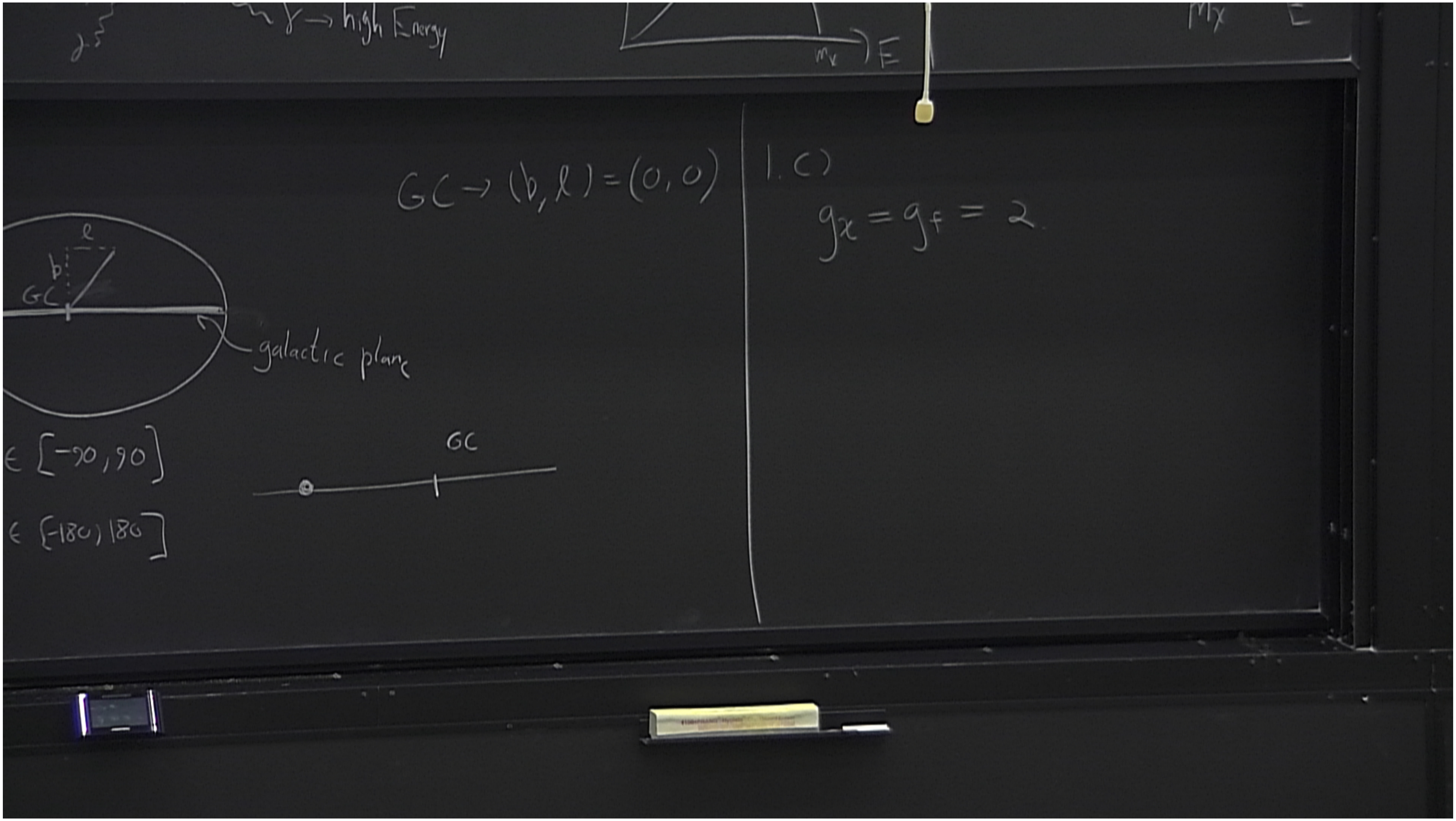


Fermi-LAT , HESS, VERITAS
20 MeV - 300 GeV
≳ 300 GeV
⟨σv⟩ / 3×10⁻²⁶ cm³/s
100
10
1
0.1
τ τ̄
b b̄
1
100
1000
mχ (GeV)


Fermi-LAT, HESS, VERITAS
20 MeV - 300 GeV
≳ 300 GeV
⟨σv⟩ / 3×10⁻²⁶ cm³/s
100
10
1
0.1
τ τ̄
b b̄
1
100
1000
mχ (GeV)
Φγ


$\langle \sigma v \rangle \cdot BR_\gamma$
$\langle \sigma v \rangle_\gamma \sim 10^{-27}\ cm^3/s$
Φ_γ
DM
130
E
$b\bar{b}$
m_χ (GeV)


ITAS
GeV
$b\bar{b}$
m_χ (GeV)
Φ_γ
DM
130
E (GeV)
$\langle \sigma v \rangle BR_\gamma$
$\langle \sigma v \rangle_\gamma \sim 10^{-27}$ cm^3/s
Continuum γ: $\langle \sigma v \rangle \leq 5\times10^{-26}$ cm^3/s


high Energy
E
1. c)
$g_\chi = g_f = 2$
$GC \to (b, \ell) = (0,0)$
ℓ
b
GC
galactic plane
GC
$\in [-90, 90]$
$\in [-180, 180]$