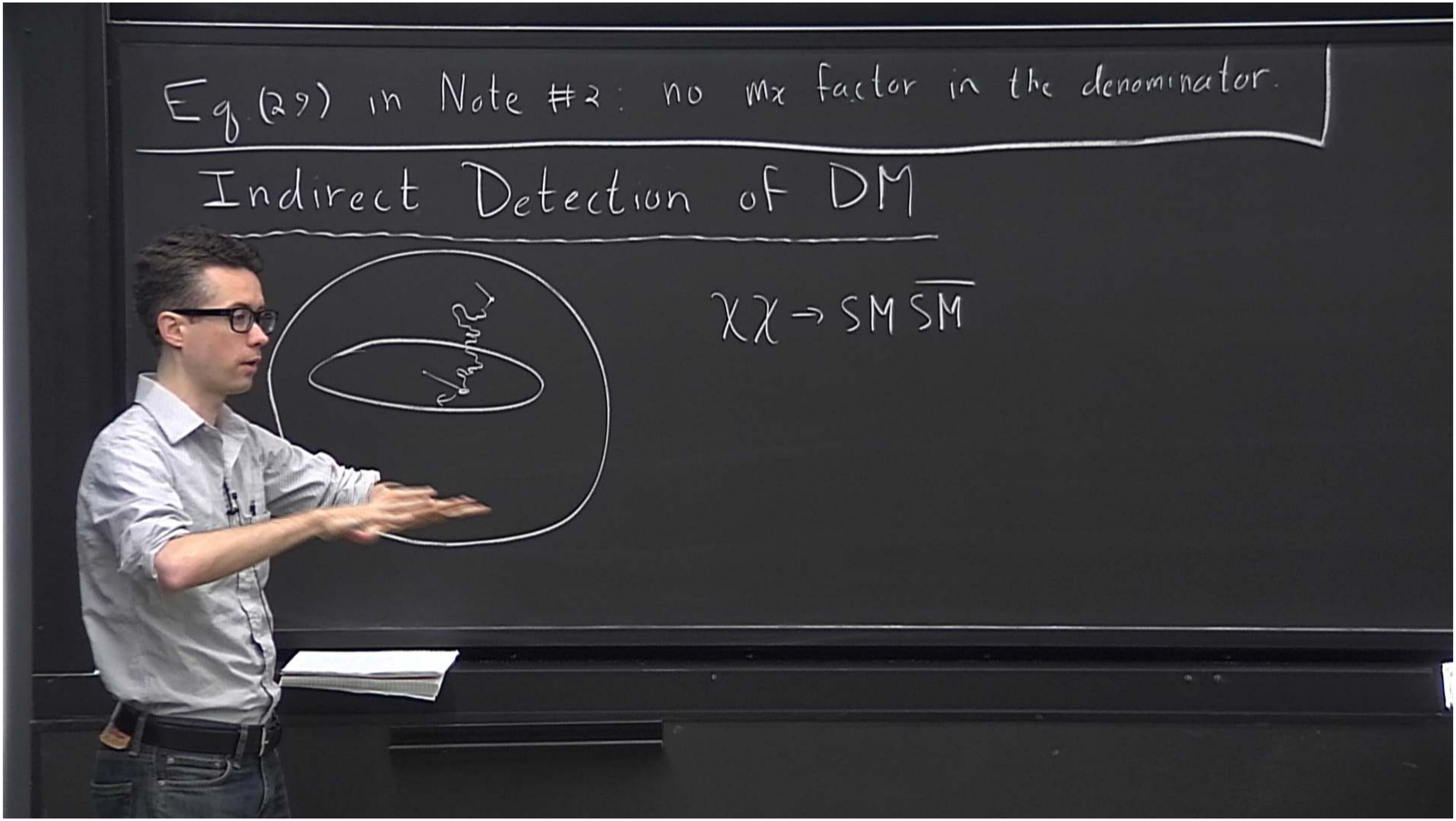
Title: Explorations in Particle Theory - Lecture 10

Date: Apr 16, 2012 09:00 AM

URL: http://pirsa.org/12040014

Abstract:


Eq.(27) in Note #2: no m_χ factor in the denominator.
Indirect Detection of DM
$\chi\chi \to SM\,\overline{SM}$

Eq. (29) in Note #2: no m_χ factor in the denominator.

Indirect Detection of DM

$$\chi\chi \to SM\,\overline{SM}$$

$$\overset{(-)}{q},\ e^\pm,\ \mu^\pm,\ \tau^\pm,\ W^\pm,\ Z^0,\ h^0,\ \overset{(-)}{\nu},\ \gamma$$

$$\overset{(-)}{p},\ e^\mp,\ \overset{(-)}{\nu},\ \gamma$$, cosmic rays from DM

To identify a signal:

- figure rate of DM annihilation
- figure out energy spectrum

particle

- model the propagation of DM-CR
- do the same for astro-CR
- measure signals!

astro

DM

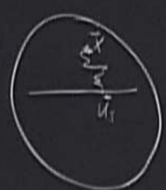
$p, e^+, \bar\nu, \gamma$, cosmic rays from DM

$\underbrace{p, \bar p, e^+, e^-}_{CR}$, γ

↳ γ-rays, X-rays, Radio Frequency (RF)

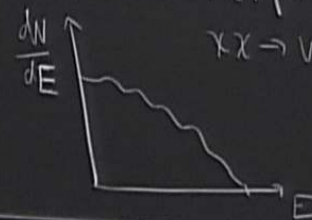
$$\dot n_\chi + 3H n_\chi = -\langle \sigma v \rangle (n_\chi^2 - n_{\chi_{eq}}^2)$$

Injection Spectrum $Q_i(\vec x, E) =$ rate of injection of species i per unit volume per unit energy



$$= \frac{1}{2} \underbrace{\left[\frac{\rho_\chi(\vec x)}{m_\chi}\right]^2}_{n_\chi(\vec x)} \langle \sigma v \rangle \underbrace{BR_i}_{\text{Branching ratio to } i} \cdot \frac{dN_i}{dE}$$

$\sim$ energy spectrum of the i-th particle per annihilation

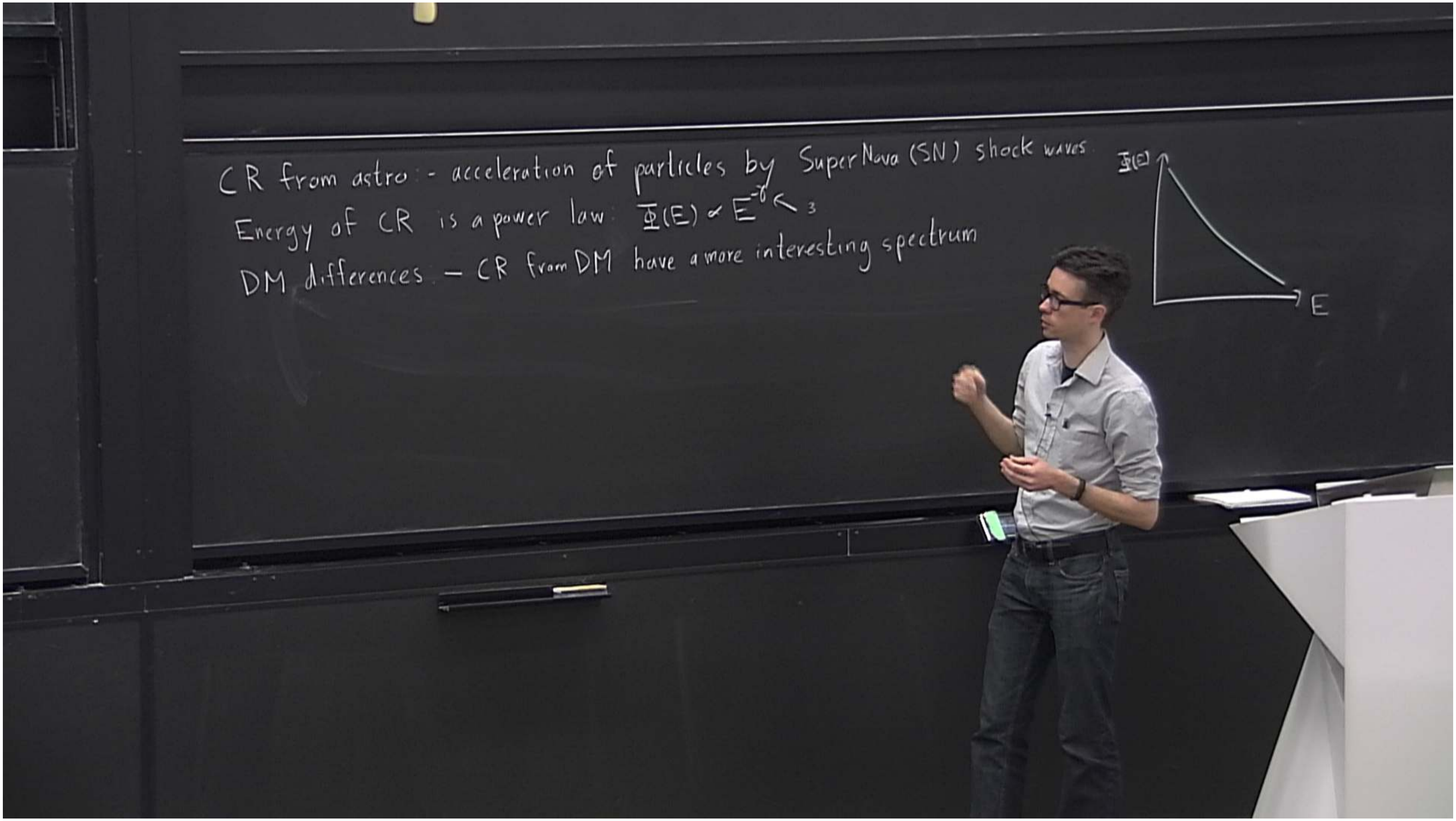


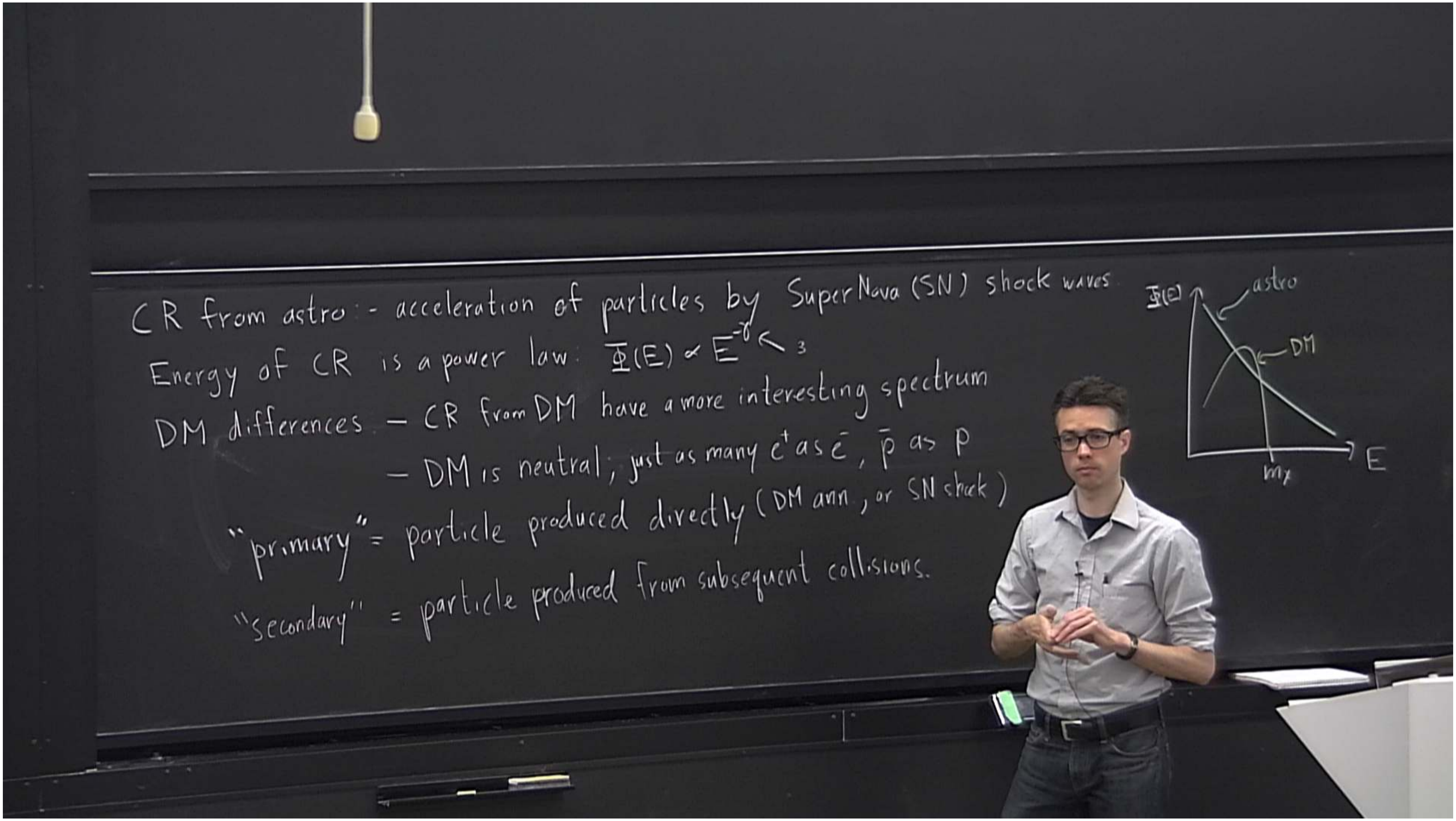
$\chi\chi \to W^+W^-$

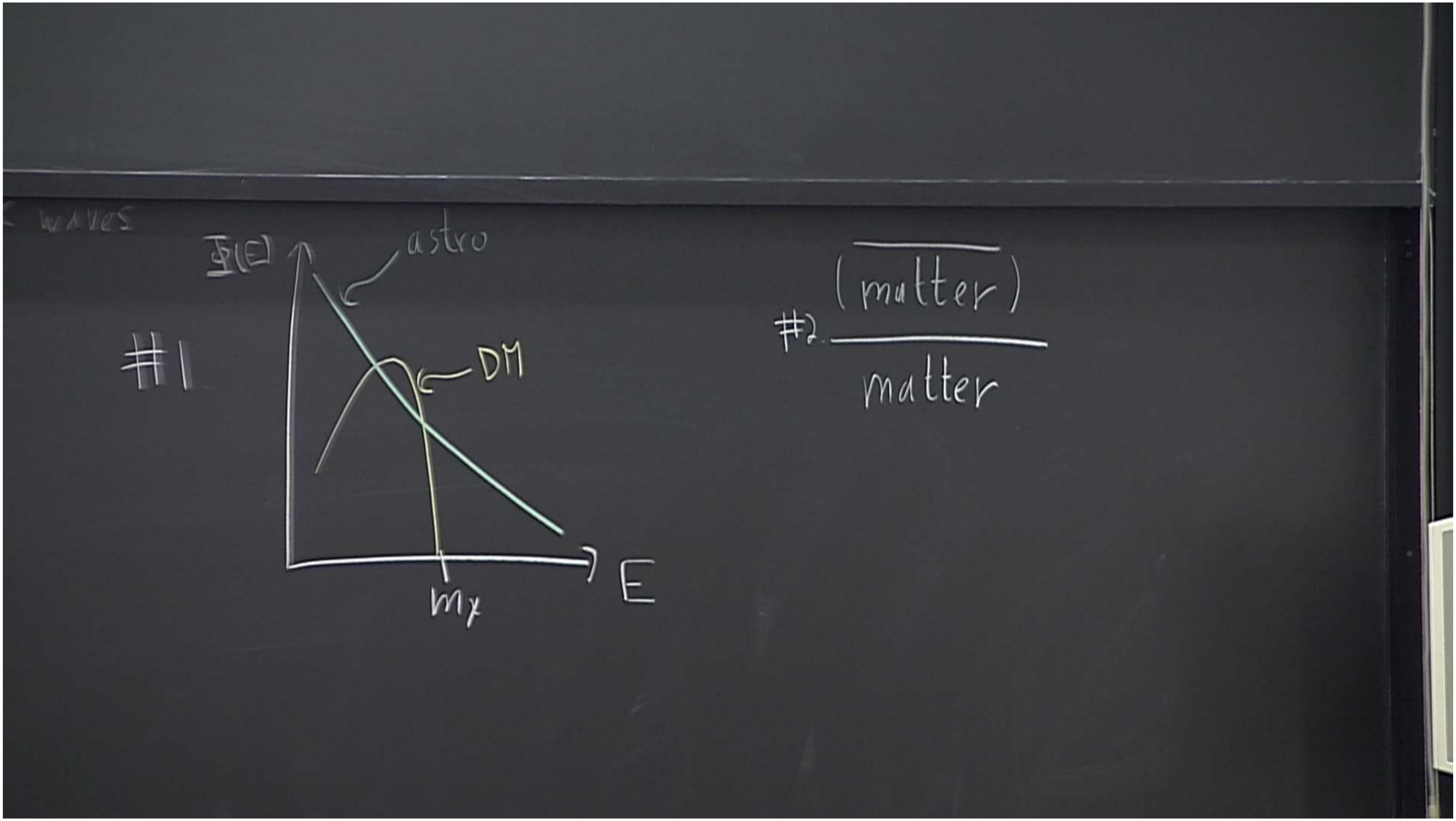
↳ $\bar\nu_e e^-$

↳ $\bar\nu_\mu \mu^-$

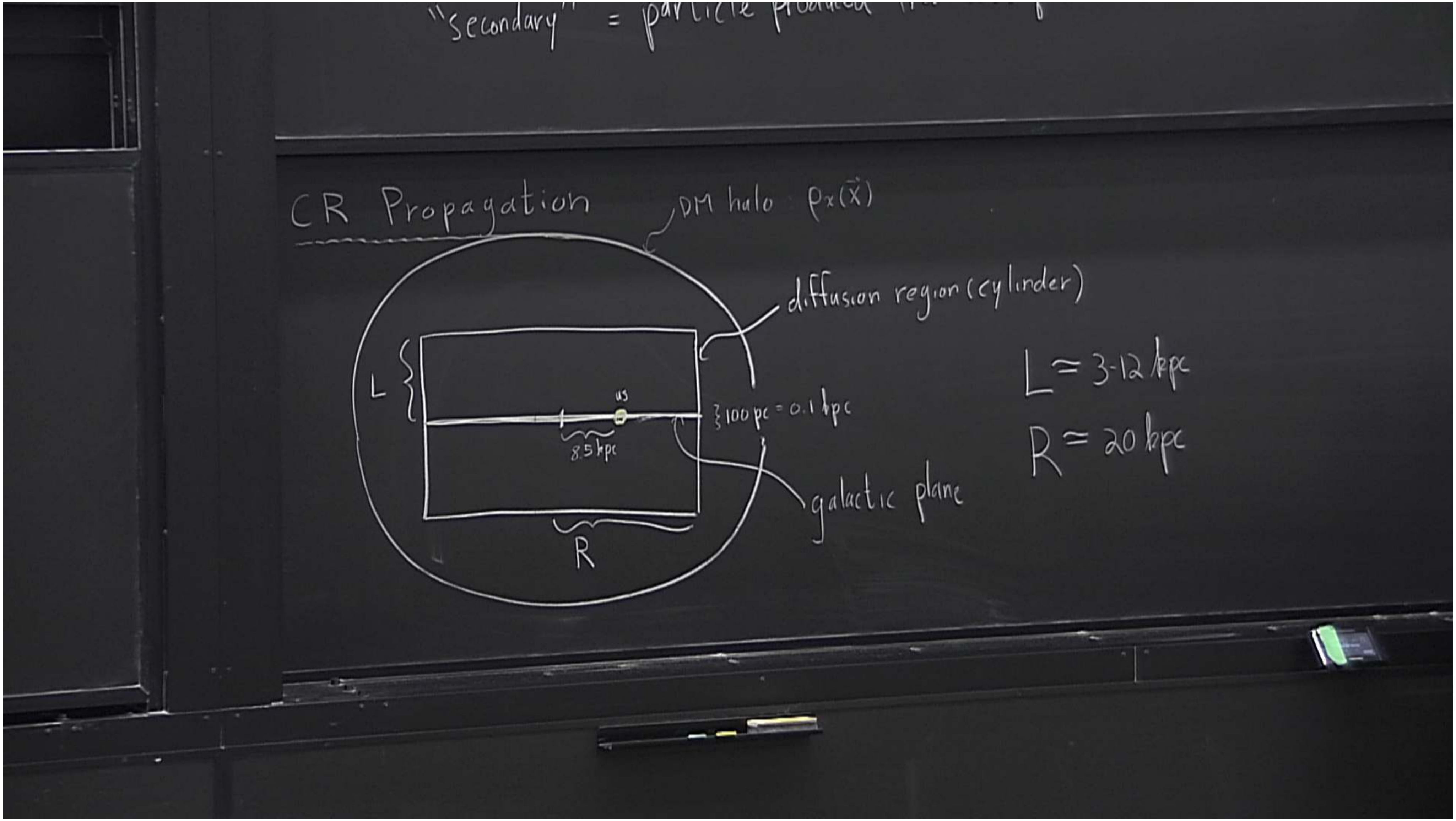
↳ $\nu_\mu \bar\nu_e e^-$


CR from astro: - acceleration of particles by SuperNova (SN) shock waves.
Energy of CR is a power law: $\Phi(E) \propto E^{-\gamma}$ ← 3
DM differences: – CR from DM have a more interesting spectrum
$\Phi(E)$
E


CR from astro: - acceleration of particles by SuperNova (SN) shock waves.
Energy of CR is a power law: $\Phi(E) \propto E^{-\gamma} \leftarrow 3$
DM differences – CR from DM have a more interesting spectrum
– DM is neutral, just as many e^+ as e^-, $\bar{p}$ as p
"primary" = particle produced directly (DM ann, or SN shock)
"secondary" = particle produced from subsequent collisions.
$\Phi(E)$
astro
DM
E
m_χ



waves
Φ(E)
astro
#1
DM
E
mχ
#2
(matter)
matter


"secondary" = particle produced
CR Propagation
DM halo $\rho_\chi(\vec{x})$
diffusion region (cylinder)
L
us
100 pc = 0.1 kpc
8.5 kpc
galactic plane
R
$L \simeq 3\text{-}12$ kpc
$R \simeq 20$ kpc

$$\Psi_i = \frac{dn_i}{dE}(t,\vec{x},E)$$

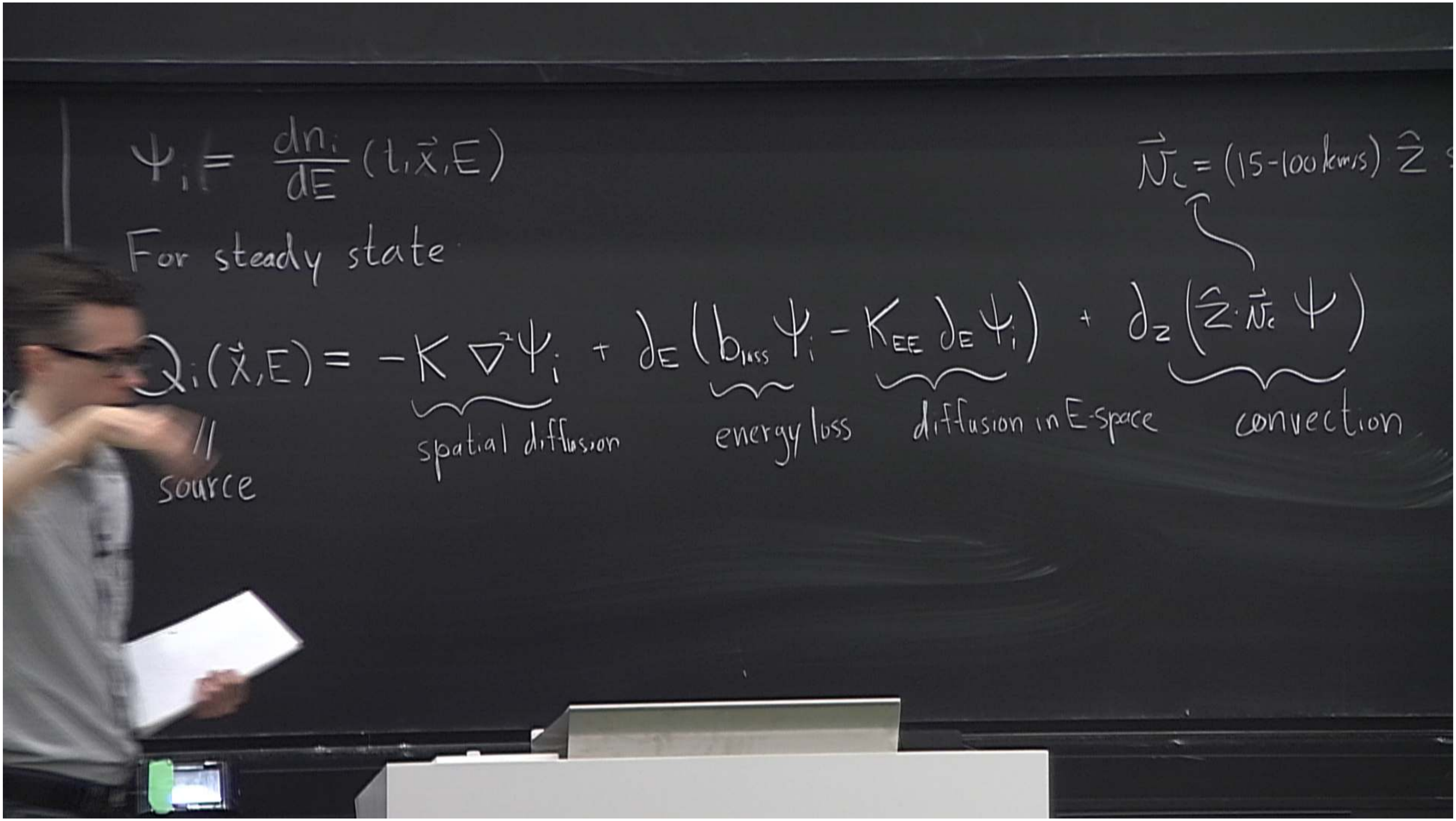
For steady state

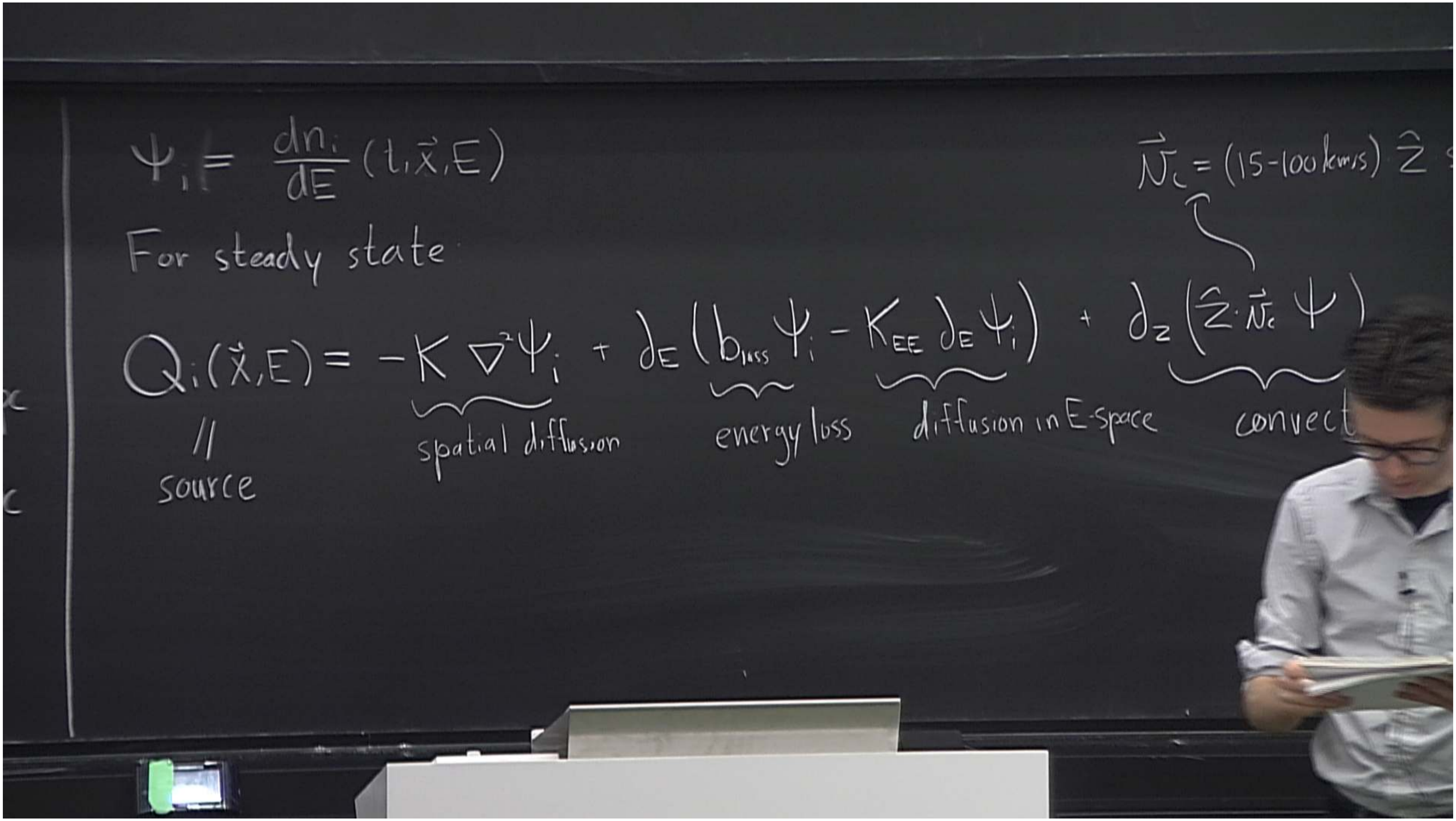
$$Q_i(\vec{x},E) = \underbrace{-K\nabla^2\Psi_i}_{\text{spatial diffusion}} + \partial_E\big(\underbrace{b_{loss}}_{\text{energy loss}}\Psi_i - K_{EE}\,\partial_E\Psi_i\big) + \partial_z\big(\hat{z}\cdot\vec{V}_c\,\Psi\big)$$

//
source

kpc

kpc


$\Psi_i = \frac{dn_i}{dE}(t, \vec{x}, E)$
$\vec{v}_c = (15\text{-}100\ \mathrm{km/s})\ \hat{z}$
For steady state
$Q_i(\vec{x}, E) = -K \nabla^2 \Psi_i + \partial_E \left(b_{loss} \Psi_i - K_{EE} \partial_E \Psi_i \right) + \partial_z \left(\hat{z} \cdot \vec{v}_c \Psi \right)$
source
spatial diffusion
energy loss
diffusion in E-space
convection


$\Psi_i = \frac{dn_i}{dE}(t, \vec{x}, E)$
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For steady state
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//
source
convect

Eq (29) in Note #2: no m_x factor in the denominator.

Standard Tool: Galprop : Moskalenko + Strong

Consistency check: B/C ratio

C = carbon = mostly primary CR

B = boron = secondary CR

$$\Psi_i(\vec{x}_\odot, E) = \int dE_s \int_{DM} d^3x_s \, G_i(\vec{x}_\odot, \vec{x}_s ; E_s \to E) \, Q_i(\vec{x}_s, E_s)$$

$\vec{x}_\odot$ = our position

E = energy we see

E_s = source energy

$\vec{x}_s$ = source position

G_i = Green's Function

$$\Phi_i(\vec{x}_\odot, E) = \text{flux we see} = \left(\frac{v}{4\pi}\right) \Psi_i(\vec{x}_\odot, E) \qquad (m^{-2} \cdot s^{-1} \cdot GeV^{-1} \cdot sr^{-1})$$

$$\Psi_i(\vec{x}_\odot, E) = \int dE_s \int_{DM} d^3x_s \; G_i(\vec{x}_\odot, \vec{x}_s ; E_s \to E)\; Q_i(\vec{x}_s, E_s)$$

$\vec{x}_\odot$ = our position; E = energy we see; E_s = source energy; $\vec{x}_s$ = source position; G_i = Green's Function

$$\Phi_i(\vec{x}_\odot, E) = \text{flux we see} = \left(\frac{v}{4\pi}\right)\Psi_i(\vec{x}_\odot, E) \qquad (m^{-2}\; s^{-1}\cdot GeV^{-1}\cdot sr^{-1})$$

$$\Phi(\vec{x}_\odot, E) = \mathcal{J}_i \cdot \int dE_s \, f_i(E_s)\, I(E, E_s)$$

$$\mathcal{J}_i = \frac{v}{8\pi}\langle \sigma v\rangle \left(\frac{\rho_\odot}{m_\chi}\right)^2 \qquad f_i = \frac{dN_i}{dE} \qquad I = \int d^3x_s\, G_i(\ldots)\left[\frac{\rho_\chi(\vec{x}_s)}{\rho_\odot}\right]^2$$